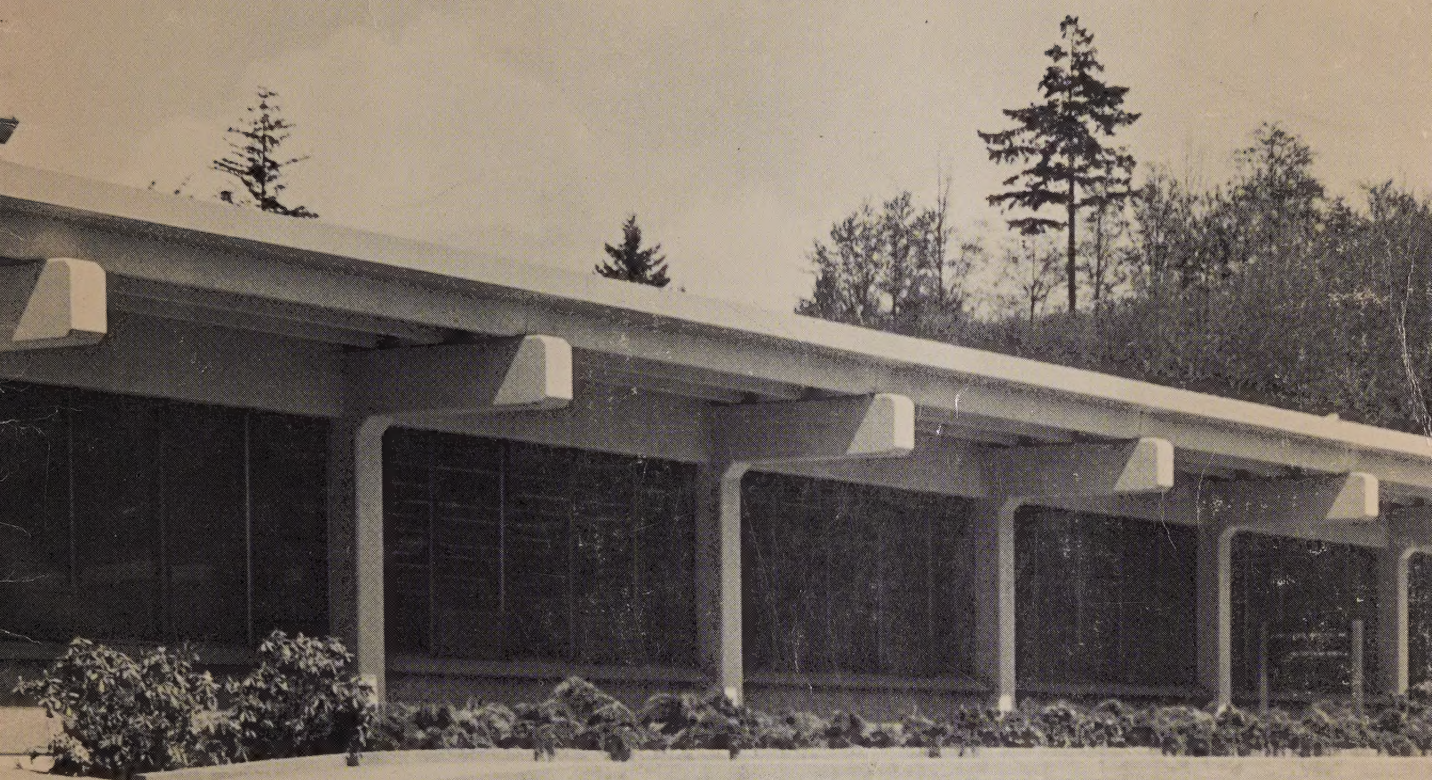


Instruction Manual



JOHN FLUKE mfg. co., inc.
SEATTLE, WASHINGTON

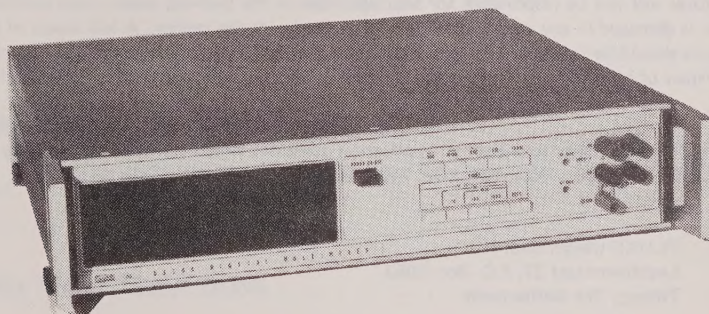




WARRANTY

JOHN FLUKE MFG. CO., INC.

P. O. Box 7428
Seattle, Washington 98133



MODEL

8350A

DIGITAL MULTIMETER
PRELIMINARY MANUAL

WARRANTY

The JOHN FLUKE MFG. CO., INC.* warrants each instrument manufactured by them to be free from defects in material and workmanship. Their obligation under this Warranty is limited to servicing or adjusting an instrument returned to the factory for that purpose, and to making good at the factory any part or parts thereof; except tubes, fuses, choppers and batteries, which shall, within one year after making delivery to the original purchaser, be returned by the original purchaser with transportation charges prepaid, and which upon their examination shall disclose to their satisfaction to have been thus defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at a nominal cost. In this case, an estimate will be submitted before work is started, if requested.

If any fault develops, the following steps should be taken:

1. Notify the John Fluke Mfg. Co., Inc.* giving full details of the difficulty, and include the Model number, type number, and serial number. On receipt of this information, service data or shipping instructions will be forwarded to you.
2. On receipt of the shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the Warranty.

SHIPPING

All shipments of John Fluke Mfg. Co., Inc.* instruments should be made via **Railway Express**** prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be thoroughly inspected immediately upon receipt. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to John Fluke Mfg. Co., Inc.* Upon receipt of this report you will be advised of the disposition of the equipment for repair or replacement. Include the model number, type number, and serial number when referring to this instrument for any reason.

The John Fluke Mfg. Co., Inc.* will be happy to answer all application questions which will enhance your use of this instrument. Please address your requests to: JOHN FLUKE MFG. CO., INC., P.O. BOX 7428, SEATTLE, WASHINGTON 98133.*

*For European customers: **FLUKE (Nederland) N.V.**
Ledeboerstraat 27, P.O. Box 5053
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Section 1

Introduction & Specifications

1-1. INTRODUCTION

1-2. The Model 8350A is a versatile digital multimeter with five full decades of digits plus a sixth digit for 20% overrange. The instrument offers five ranges of dc voltage measurement including autorange, autopolarity, and active filtering. Four ranges of ac voltage measurement and five ranges of resistance measurement are also included.

1-3. The Model 8350A uses the Fluke-developed Recirculating Remainder* A-to-D conversion system which determines the most significant digit by a very accurate direct comparison process, stores a sample of the remaining

input voltage, and serially determines the value of succeeding digits from this sample. This process requires only one decade of BCD counter and one decade of precision resistive ladder network for five complete decades of conversion. Multiple use of components results in low parts count and low power consumption ensuring high reliability.

1-4. The ac voltage measurement function features a 50Hz to 20kHz midband with excellent accuracy from 30Hz and 100kHz. The mv function measures to 100mV at full range with 1uV of resolution. The resistance function uses a modified four-terminal configuration on the two lowest ranges.

1-5. SPECIFICATIONS

DC VOLTS

INPUT SPECIFICATIONS

Ranges	Input Impedance
± 100mV	10 ⁸ ohms
±1000mV	10 ⁹ ohms
±10V	10 ¹⁰ ohms
±100V	10 ⁷ ohms
±1000	10 ⁷ ohms
	< 100 pf

Range Selection

manual or automatic within millivolts or volts ranges

Resolution

0.001% of range 1μV on ±100mV range

Overrange

20% ± 1100V maximum on ±1000V range

Overload

1100V DC or RMS 1500V peak may be continuously applied to any range without damage

ACCURACY SPECIFICATIONS ±(% input + % range)

	±10V, ±100V, ± Ranges	±1000mV Range	±100mV Range
24 Hour 23°C ±1°C	±(0.005 + 0.001)	±(0.005 + 0.001)	±(0.005 + 0.004)
90 Day 25°C ±5°C	±(0.01 + 0.002)	±(0.01 + 0.002)	±(0.01 + 0.005)
1 Year 25°C ±5°C	±(0.015 + 0.005)	±(0.015 + 0.002)	±(0.015 + 0.005)
Temperature Coefficients	±(0.0007 + 0.0003)/°C	±(0.0007 + 0.0003)/°C	±(0.0007 + 0.0005)/°C

OPERATION SPECIFICATIONS

Noise Rejection		Zero Stability	
	DC	AC	Better than 8μV for 90 days
Common Mode	> 140 db	> 140 db, 60Hz and above	Response Time
1KΩ in either			1000V, ±100V, 10V Ranges
Lead			< 500 MS
Normal Mode		> 60 db, 50Hz and above	1000mV Range
			< 1 Second
			100mV Range
			< 3 Seconds

AC VOLTS

INPUT SPECIFICATIONS

Ranges	Input Impedance	Range Selection
1V	1 Megohm	manual or automatic
10V	shunted by	Overrange
100V	< 100pf	20%, 1100V RMS maximum on 1000V range
1000V		Overload
		1100V RMS on any range, 1500V peak AC + DC
Resolution		Conversion
±0.001 % of range '10µV on 1V range'		Average responding corrected to indicate RMS value

ACCURACY SPECIFICATION 25°C ±5°C 0.001V to 1100V ±(% of input + % range)

	24 Hour	90 Day	1 Year
50Hz - 20kHz	±(0.1 + 0.005)	±(0.1 + 0.03)	±(0.1 + 0.04)
20kHz - 50kHz	±(0.2 + 0.005)	±(0.2 + 0.03)	±(0.2 + 0.04)
30Hz - 50Hz	±(0.5 + 0.005)	±(0.5 + 0.03)	±(0.5 + 0.04)
50 kHz - 100 kHz			
Temperature	±(0.002 + 0.001)/°C		
Coefficient			
0°C - 50°C			

- (1) Accuracies stated without front panel AC zero adjustment for intervals indicated. With adjustment accuracy of ±0.005% of range may be obtained at any time throughout a six month period.
- (2) Input volt x hertz product should not exceed 2 x 10⁷.
- (3) At 50Hz to 20kHz between 500V and 1100V, accuracy = ±0.15% of input.

OPERATING SPECIFICATIONS

Noise Rejection	Response Time
DC to 60Hz, > 120 db Common mode with up to 100Ω unbalance in either lead	500 Milliseconds
	Maximum common mode voltage 1000V DC or peak AC

RESISTANCE

INPUT SPECIFICATIONS

Ranges	Source Current	Range Selection
1kΩ	1.1mA	manual or automatic, <i>10MΩ range selected manually</i>
10kΩ	110μA	Configuration
100kΩ	100μA	4 terminal through 10kΩ range
1000kΩ	10μA	Maximum voltage on input
10MΩ	1μA	30V RMS <i>fuse protected</i>
Resolution		Response Time
0.001% of range, <i>10 milliohm on 1k range</i>		1.5 seconds maximum

ACCURACY SPECIFICATIONS ± (% of input + % of range)

	1k-1000kohm Ranges	10 megohm Range
24 Hour 23°C ± 1°C	± (0.008 + 0.002)	± (0.04 + 0.002)
90 Day 25°C ± 5°C	± (0.01 + 0.002)	± (0.05+ 0.002)
1 Year	± (0.015 + 0.005)	± (0.06 + 0.005)
Temperature Coefficient 0°C - 50°C	± (0.0007 + 0.0003) / °C	± (0.003+0.0003) / °C

GENERAL

Environmental

Temperature	Operating	Storage
Altitude	0°C - 50°C	-40°C to +75°C
Humidity	10,000 feet	50,000 feet
	0 to +25°C	
	up to 80% RH	
	+25°C to 50°C	
	up to 70% RH	

Maximum Inputs	Hi to Lo See individual specifications
	Lo to Guard 100V
	Guard to chassis 1000V DC or Peak AC

Price

8350A Multimeter \$1,495

Accessories

M03-205-600 Rack Mounting Brackets	\$ 15
M00-280-610 Rack Slides	50
A-90 Shunt	255
80F-5 HV Probe	275
80F-15 HV Probe	325
80RF RF Probe	75

Power	115/230V ± 10%
	50 - 440Hz
	Less than 20w

Weight
16 lbs (7, 3kg)

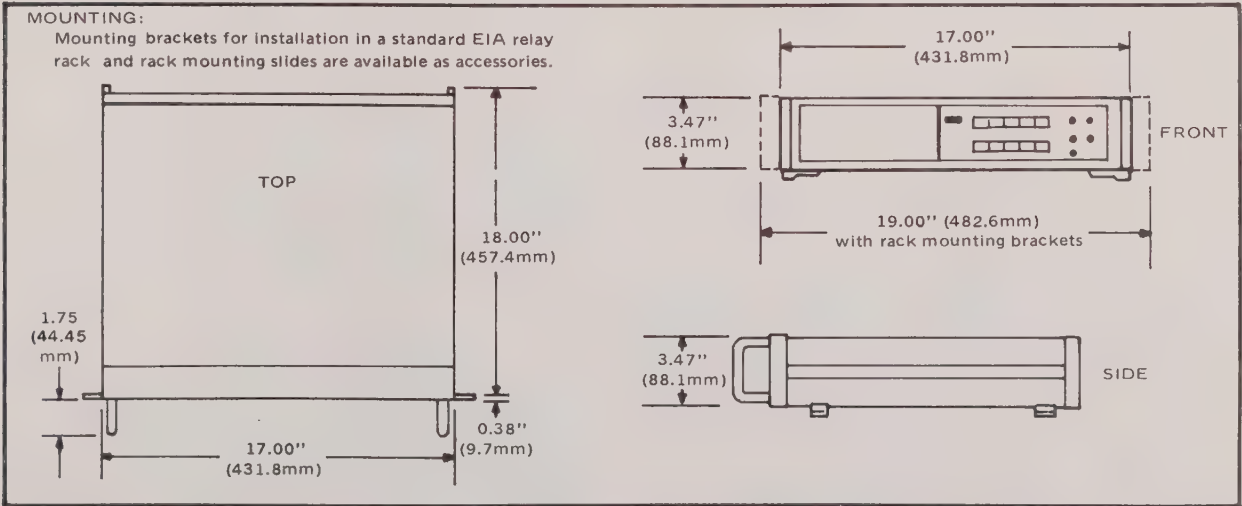


Figure 1-1. MODEL 8350A OUTLINE DRAWING

Section 2

Operating Instructions

2-1. INTRODUCTION

2-2. This section contains operating instructions and applications information for the Model 8350A Digital Multimeter. Included in the instructions is a detailed description of the instrument controls, terminals, and indicators and an operational check which verifies satisfactory operation of the instrument using only front panel controls. If any problem is encountered in operating the instrument, contact the nearest John Fluke sales representative or write directly to the John Fluke Mfg. Co., Inc. Please include the instrument serial number when writing.

2-3. INSTALLATION

2-4. The Model 8350A is supplied with non-marring feet and tilt-down bail for bench or field use. Rack mounting kits are available. Kit M03-205-600 provides rack ears and hardware for mounting the instrument in a standard 19-inch rack. Kit M00-280-610 provides 18-inch rack slides. Rack mounting procedures are shown in Figures 2-9 and 2-10.

2-5. INPUT POWER REQUIREMENTS

2-6. The instrument operates on 115 or 230 volts, 50 Hz to 440 Hz ac power. Before applying power to the instrument, note the position of the 115/230 volt slide switch at the rear of the instrument. If the switch does not indicate the desired operating voltage, place the switch in the

desired position and ensure that the proper line fuse is installed.

WARNING!

The center pin on the polarized three-prong plug connects the instrument case to power system ground. If a three-to-two-wire adapter is used, ensure that the instrument ground wire is connected to a high quality earth ground.

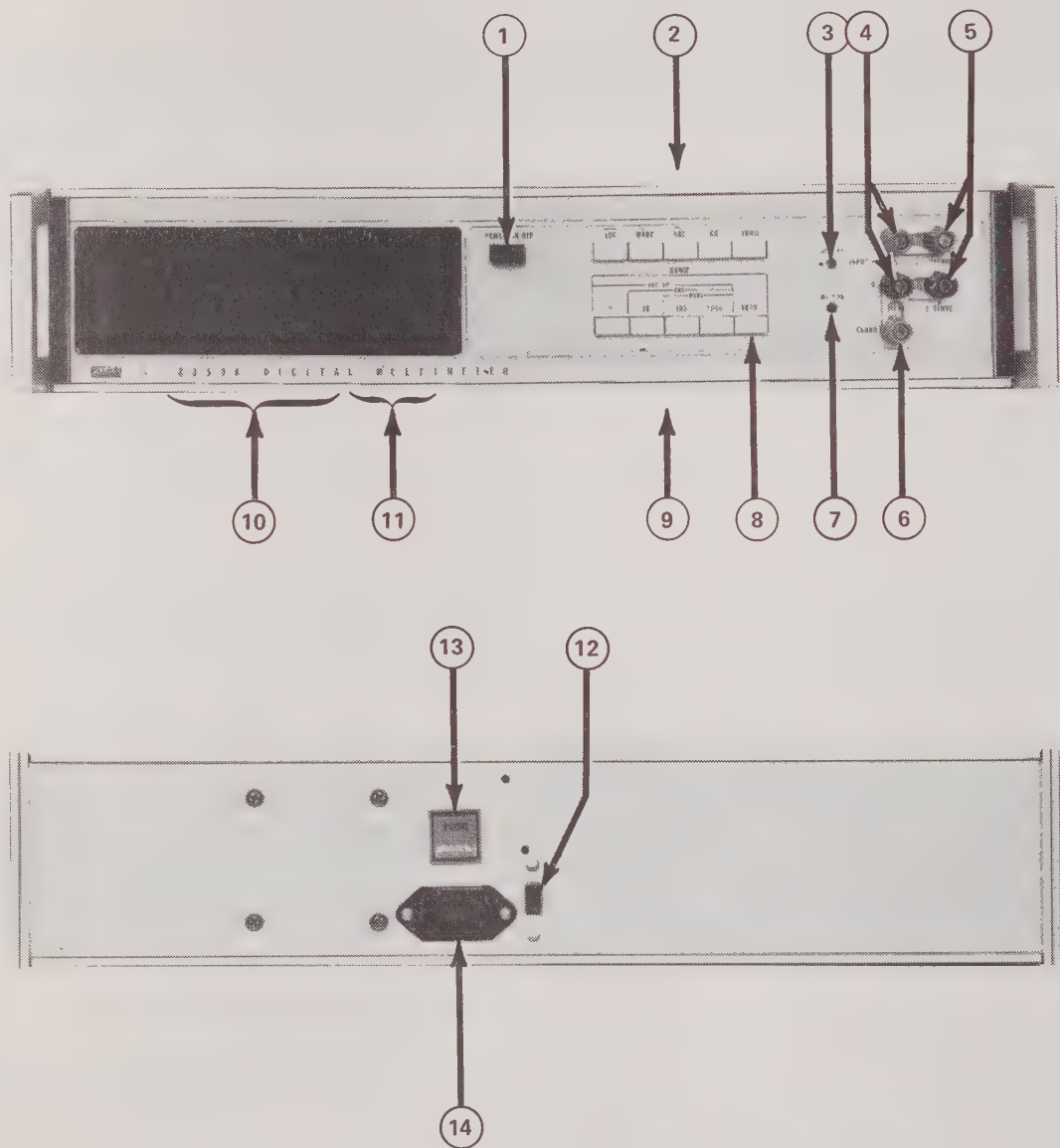
2-7. OPERATING FEATURES

2-8. The names and functions of the front and rear panel controls, terminals, and indicators are shown in Figure 2-1.

2-9. OPERATIONAL CHECK

2-10. This test verifies satisfactory operation of the instrument using only front panel controls. It is intended as a quick functional check only. In consideration of possible wide variation in ambient temperature, the tolerances on readouts have been extended accordingly.

- a. Connect the Model 8350A to a source of 50 Hz to 440 Hz ac power and depress the POWER-ON switch.



REF. NO.	NAME	FUNCTION
1	POWER Switch	Alternate action pushbutton switch controls input power to the instrument. When depressed, instrument is ON; when released, instrument is OFF.
2	FUNCTION Switches	Five pushbutton switches select the desired operating mode. All switches are mechanically interlocked so that only one function at a time can be called.

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS (Sheet 1 of 3)

REF. NO.	NAME	FUNCTION												
2	VDC	Places instrument in dc voltage mode and provides full-scale voltage ranges of 10, 100 and 1000 volts.												
	MVDC	Places instrument in dc millivolt mode and provides full-scale voltage ranges of 100 and 1000 millivolts.												
	VAC	Places instrument in ac voltage mode and provides full-scale voltage ranges of 1, 10, 100 and 1000 volts.												
	KΩ	Places instrument in kilohm mode and provides full-scale resistance ranges of 1, 10, 100 and 1000 kilohms.												
	10 MΩ	Places instrument in 10 megohm mode, with range fixed at 10 megohms full-scale, independent of the four range switches.												
3	AC ZERO	AC ZERO control, adjusted for a readout of 000.00 with VAC FUNCTION switch depressed and 1000 volt RANGE switch depressed.												
4	INPUT Terminals	HI, LO input connections for dc voltage, ac voltage and resistance measurements.												
5	Ω SENSE Terminals	For four-terminal resistance measurements on 1K and 10K range.												
6	GUARD Terminal	Connects to internal guard chassis. When properly connected externally, provides increased ac and dc common mode rejection. May be connected directly to the LO terminal or disconnected from the LO terminal and driven by a separate GUARD potential.												
7	MV ZERO	Millivolt zero control, adjusted for a readout of 00.000 with MVDC FUNCTION switch depressed and 100 millivolt RANGE switch depressed.												
8	AUTO	Places instrument in autorange mode, providing automatic ranging for each function and its range complement. The AUTO range switch is mechanically interlocked with the four RANGE switches so that only one range function at a time can be called. Calling a range not available for the called function places the instrument in autorange.												
9	RANGE Switches	Four pushbutton switches select the full-scale input range for voltage and resistance measurements. The range complement for each function is as follows: <table><tr><th>FUNCTION</th><th>FULL SCALE RANGES AVAILABLE</th></tr><tr><td>VDC</td><td>10, 100 and 1000 Vdc</td></tr><tr><td>MVDC</td><td>100 and 1000 mVdc</td></tr><tr><td>VAC</td><td>1, 10, 100 and 1000 Vac</td></tr><tr><td>KΩ</td><td>1k, 10k, 100k and 1000k</td></tr><tr><td>10 MΩ</td><td>Fixed at 10 MΩ</td></tr></table>	FUNCTION	FULL SCALE RANGES AVAILABLE	VDC	10, 100 and 1000 Vdc	MVDC	100 and 1000 mVdc	VAC	1, 10, 100 and 1000 Vac	KΩ	1k, 10k, 100k and 1000k	10 MΩ	Fixed at 10 MΩ
FUNCTION	FULL SCALE RANGES AVAILABLE													
VDC	10, 100 and 1000 Vdc													
MVDC	100 and 1000 mVdc													
VAC	1, 10, 100 and 1000 Vac													
KΩ	1k, 10k, 100k and 1000k													
10 MΩ	Fixed at 10 MΩ													

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS (Sheet 2 of 3)

REF. NO.	NAME	FUNCTION										
10	Readout Tubes	Six neon indicator tubes display the instrument readout from left to right, with the overrange digit displayed in the left-most tube. All of the tubes (except the overrange indicator and the extreme right-hand tube) display a decimal point, which is controlled by the range switch. For example, an overload readout on each range would appear as follows: <table><tr><th>RANGE</th><th>READOUT</th></tr><tr><td>1</td><td>1.19999</td></tr><tr><td>10</td><td>11.9999</td></tr><tr><td>100</td><td>119.999</td></tr><tr><td>1000</td><td>1199.99</td></tr></table>	RANGE	READOUT	1	1.19999	10	11.9999	100	119.999	1000	1199.99
RANGE	READOUT											
1	1.19999											
10	11.9999											
100	119.999											
1000	1199.99											
11	Function/Status Indicators	Seven indicators, illuminate to indicate function and status as follows:										
	OVER	Overload input applied to instrument (over the 20% overrange capability).										
	AC	Instrument operating in ac voltage mode.										
	KΩ	Instrument operating in kilohm mode.										
	MΩ	Instrument operating in 10 megohm mode.										
	MV	Instrument operating in dc millivolts mode.										
	DC+	DC voltage applied to instrument, with HI input terminal positive with respect to LO input terminal. Also illuminates when MVDC is called.										
	DC—	DC voltage applied to instrument, with HI input terminal negative with respect to LO input terminal. Also illuminates when MVDC is called.										
12	115/230 Volt Switch	Slide switch selects either 115 or 230 volts, 50 Hz to 440 Hz operation.										
13	Line Fuse	AGC ½ ampere fuse protects instrument from overloads.										
14	AC Line Connector	Mates with three-wire line cord for connection to 115/230 volts, 50 Hz to 115/230 volts, 50 Hz to Hz ac line.										

Figure 2-1. CONTROLS, TERMINALS, AND INDICATORS (Sheet 3 of 3)

b. Set the controls and connect the INPUT terminals as shown in Figure 2-2. The readout should be as indicated.

2-11. OPERATION AND APPLICATIONS

2-12. The following paragraphs describe the basic measurement and operating procedures associated with each of

the instrument functions:

- DC Voltage Measurement
- AC Voltage Measurement
- Resistance Measurement

2-13. The measurement instructions are summarized briefly in Figure 2-3.

FUNCTION	RANGE	INPUT TERMINALS	READOUT
VDC	10	Open	Instrument measures changing voltage on input stray capacitance as it is being charged by the small input bias current.
VDC	100	Open	00.000 $\pm$ 5 digits
VDC	1000	Open	000.00 $\pm$ 5 digits
MVDC	100	Open	Instrument measures changing voltage on input stray capacitance as it is being charged by the small input bias current.
VAC	1000	Shorted	000.00 $\begin{matrix} +30 \\ -0 \end{matrix}$ digits
VAC	1	Shorted	.00000 $\pm$ 20 digits of above.
VAC	AUTO	Shorted	Same as above.
K Ω	AUTO	Open	1199.99 OVERload indicator lights.
K Ω	AUTO	Shorted	.00000 $\begin{matrix} +5 \\ -0 \end{matrix}$ digits
10 M Ω		Open	11.9999 OVERload indicator lights.
10 M Ω		Shorted	0.0000 $\begin{matrix} +5 \\ -0 \end{matrix}$ digits
NOTE: In VAC function, shorted input, the digits evident in the readout are a result of residual noise in the instrument. This noise signal will cause an insignificant error as long as ac input signals of 1 millivolt or larger are present at the input. Although the instrument is usable below 1 millivolt, the noise may cause significant errors.			

Figure 2-2. MODEL 8350A OPERATIONAL CHECK.

MEASUREMENT	MODEL 8350A			REMARKS
	FUNCTION	RANGE	INPUT CONNECTIONS	
$\pm$ DC Voltage	VDC	10v, 100v, 1000v, AUTO	Front panel HI,LO terminals.	Autoranges automatically if range is not manually selected. Does not autorange between VDC and MVDC. Ω SENSE terminals may be used on 1k and 10k ranges for remote sensing, i.e., four-terminal ohms measurements.
	MVDC	100 mv, 1000 mv, AUTO		
AC Voltage	VAC	1v, 10v, 100v, 1000v, AUTO		
Kilohms, 0 to 1000k	K Ω	1k, 10k, 100k 1000k, AUTO		
Megohms,	10 M Ω	Fixed		

Figure 2-3. CONDENSED MEASUREMENT INSTRUCTIONS.

2-14. DC Voltage Measurement

2-15. The Model 8350A provides dc voltage measuring capability in five full-scale ranges. The dc volts function provides ranges of 10, 100, and 1000 volts, and the millivolts function provides ranges of 100 and 1000 millivolts. Ranging may be selected for either manual or automatic operation within the VDC or MVDC functions; however, autoranging does not occur between the VDC and MVDC functions. Autopolarity, a fully guarded input, and a fully buffered three-pole (plus notch) active filter are featured. The following steps describe the dc voltage measurement procedure:

- a. Place the Model 8350A in operation by connecting it to an appropriate ac power source and operating the front panel POWER switch.
- b. Select dc voltage mode by depressing either the VDC function switch or the MVDC function switch.
- c. Select the desired range by depressing the corresponding range switch or, if autoranging is desired, depressing the AUTO RANGE switch. In autorange, the instrument will automatically accommodate any voltage within the range of the selected function. In MVDC function, the instrument will autorange between the 100 and 1000 millivolt ranges; and in VDC function, the instrument will autorange between the 10, 100 and 1000 volt ranges.
- d. Connect the GUARD terminal to the LO input terminal or, if desired, disconnect the GUARD terminal from the LO terminal and drive the GUARD by applying a separate GUARD potential.
- e. Connect the voltage to be measured to the HI, LO INPUT terminals. The readout will correspond to the input voltage with the decimal point positioned according to the range. The polarity indicator will register DC+ if the HI terminal is positive with respect to the LO terminal and DC- if the HI terminal is negative with respect to the LO terminal.

2-16. AC Voltage Measurement

2-17. The instrument provides ac voltage measurement capability in four full-scale ranges of 1, 10, 100 and 1000 volts. The full frequency coverage is 30 Hz to 100 kHz, with optimum accuracy in the mid-band of 50 Hz to

20 kHz. Selection of manual ranging or autoranging is made at the front panel. The following steps describe the basic ac voltage measurement procedure:

- a. Select the ac voltage mode by depressing the VAC function switch.
- b. Select the desired range by depressing the corresponding RANGE switch or, if autoranging is desired, depress the AUTO switch. In autorange the instrument will automatically accommodate any voltage within the range of the selected function.
- c. Connect the GUARD terminal to the LO input terminal or, if desired, disconnect the GUARD terminal from the LO terminal and drive the GUARD by applying a separate GUARD potential.
- d. Connect the voltage to be measured to the HI and LO INPUT terminals. The readout will correspond to the input voltage, with the decimal point positioned according to the range.

2-18. Resistance Measurement

2-19. The instrument provides resistance measurement capability in five full-scale ranges of 1, 10, 100 and 1000 kilohms and 10 megohms. Selection of manual ranging or autoranging is made at the front panel. The following steps describe the basic resistance measurement procedure:

- a. Select the ohms mode by depressing either the K Ω function switch or the 10 M Ω function switch.
- b. If K Ω function is used, select the desired range by depressing the corresponding RANGE switch or, if autoranging is desired, depressing the AUTO switch. In autorange, the instrument will accommodate any resistance within the range of the selected function.
- c. If 10 M Ω function is used, the range will be fixed at 10 M Ω full scale, independent of the range switch positions.
- d. Connect the GUARD terminal to the LO input terminal or, if desire, disconnect the GUARD terminal from the LO terminal at the front panel, but drive the GUARD by applying a separate GUARD potential (see paragraph 2-23, Guarded Measurements).

- e. Connect the resistance to be measured to the HI, LO INPUT terminals.
- f. If it is suspected that the resistance of the connecting leads will be excessive, due to lead length for example, an increase in accuracy will be obtained by utilizing the 4-terminal ohms capability. The increase in accuracy will depend on the ratio of the lead resistance to the unknown resistance. For low values of unknown resistance, the 4-terminal connection affords a significant increase in accuracy. The connections should be as shown in Figure 2-4.

NOTE!

When 4-terminal resistance measurements are not made, the Ω SENSE terminals must be connected to the input terminals as shown in Figure 2-8A to ensure proper instrument operation on the 1K and 10K ranges.

- g. The instrument readout will correspond to the input resistance, with the decimal point positioned according to range selected.

2-20. OPERATING NOTES

2-21. Overload Protection

2-22. The Model 8350A is protected against overload in each function and on all ranges. The following table lists

the maximum voltages that may safely be applied to the instrument, on all ranges.

FUNCTION	MAXIMUM INPUT
VDC	1100 vdc or rms (1500v peak ac)
MVDC	1100 vdc or rms (1500v peak ac)
VAC	1100v rms ($\leq \pm 1100$ v superimposed dc is allowable provided that total peak voltage does not exceed 1500v).
K Ω , 10 M	Fused at 50 ma.

2-23. Guarded Measurements

2-24. Significant errors in ac and dc measurements arise out of undesired conversion of common mode signals (i.e., Signals of like properties) to normal mode and out of ambient noise induced into unshielded input leads. These errors add to the apparent amplitude of the unknown.

2-25. The Model 8350A has a system of shields and guards that function (when properly connected) to minimize common mode-to-normal mode signal conversion and induced noise, thereby providing the user with a very versatile system capable of fully-floating measurements without significant degradation of accuracy.

2-26. The following paragraphs describe some significant sources of errors and provide recommendations for use of the guard to reduce or eliminate these errors.

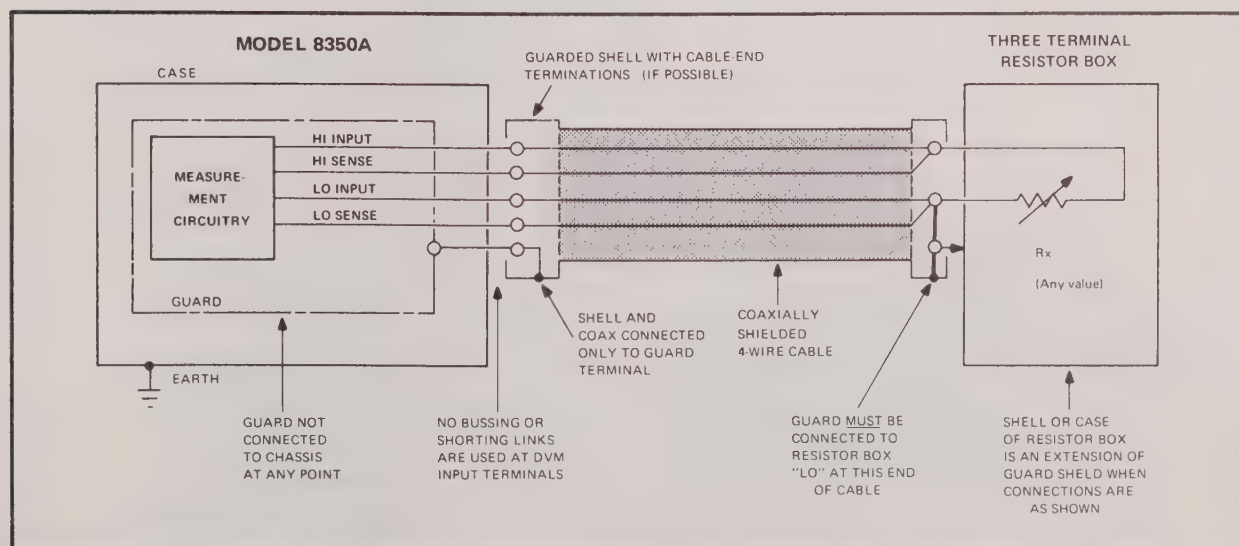


Figure 2-4. PROPER GUARD CONNECTIONS FOR FOUR-TERMINAL RESISTANCE MEASUREMENT SYSTEM

2-27. INPUT IMPEDANCE

2-28. Since measurement current flows equally in both leads, as shown in Figure 2-5, it creates an error equal to the following:

$$E_{R01} + E_{R02} = (R_{01} + R_{02}) I_M,$$

Where $R_{01} + R_{02}$ = Signal lead resistances

$E_{R01} + E_{R02}$ = Voltage developed in leads due to flow of measurement current

I_M = Current flowing in instrument input circuitry.

2-29. By the principle of superposition, this effect may be considered independently from other phenomenon.

2-30. COMMON-MODE REJECTION RATIO (CMRR)

2-31. A path for common-mode currents is created by undesired stray impedances Z_1 and Z_2 , which represent leakage resistances and stray capacitance between measurement circuit and guard and between guard and case, as shown in Figure 2-5. These impedances enable frequency-dependent currents to flow in the input leads to the instrument when common-mode voltages are applied. Current flows predominantly in the low-input lead (I_L) because I_M is designed to be very low. I_H is therefore very low

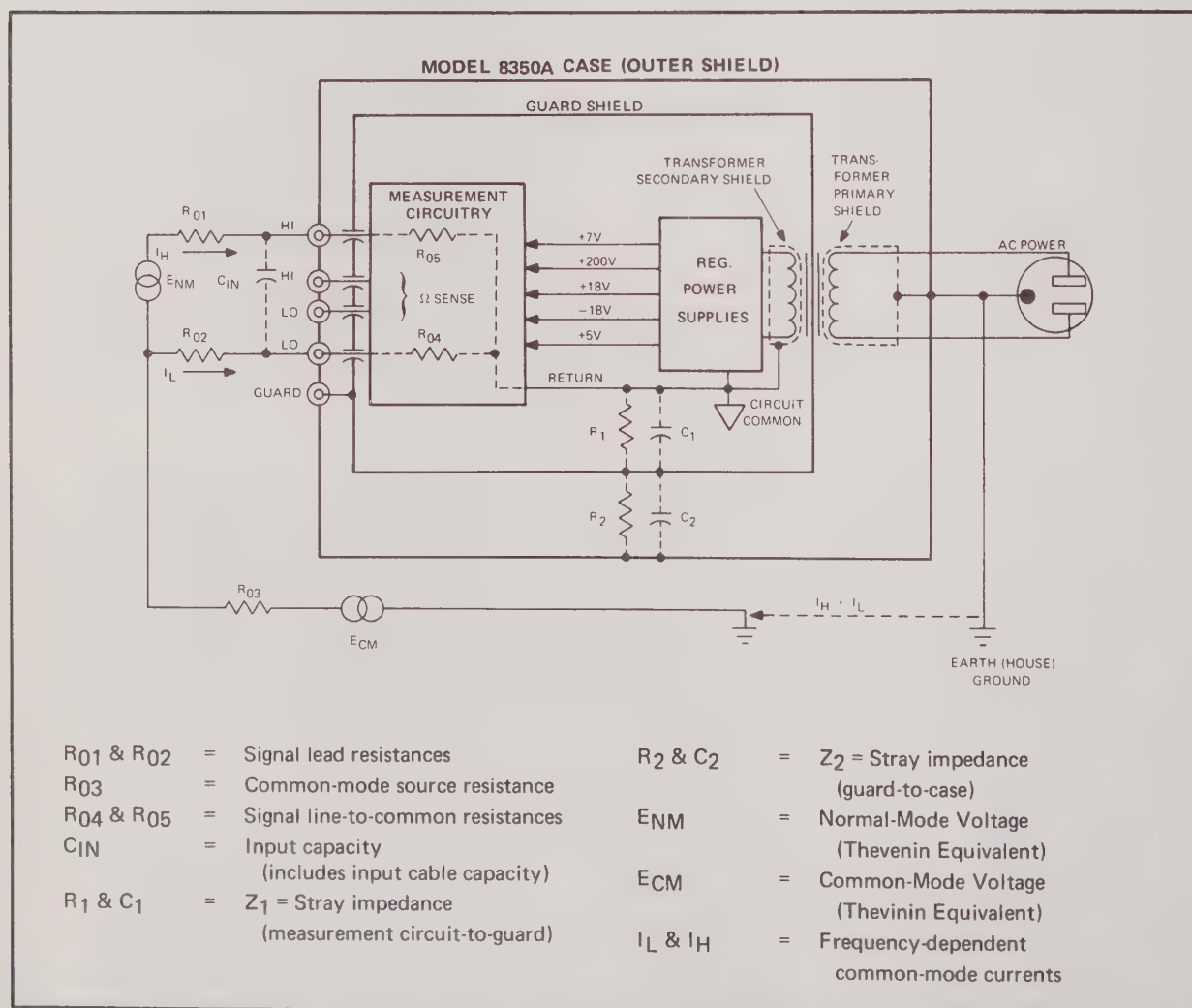


Figure 2-5. FLOATING DVM MEASUREMENT SYSTEM SHOWING GENERATION OF COMMON-MODE SIGNALS.

(i.e., R_{04} is very low and R_{05} is very high), and current I_L has a magnitude of:

$$I_L = \frac{E_{CM}}{R_{03} + R_{02} + R_{04} + Z_1 + Z_2}$$

As a result of I_L , an error voltage is developed across R_{02} whose magnitude is:

$$R_{02} I_L = E_{R02}$$

Substituting for I_L we have:

$$R_{02} \left[\frac{E_{CM}}{R_{03} + R_{02} + R_{04} + Z_1 + Z_2} \right] = E_{R02}$$

and rearranging we have:

$$\frac{E_{CM}}{E_{R02}} = \frac{R_{03} + R_{02} + R_{04} + Z_1 + Z_2}{R_{02}} \approx \frac{Z_1 + Z_2}{R_{02}}$$

if

$$Z_1 \gg R_{03}, R_{04}, R_{02}$$

and

$$CMRR \approx 20 \log_{10} \left[\frac{Z_1 + Z_2}{R_{02}} \right], \text{ expressed in DB.}$$

2-32. Other factors affecting CMRR are the input capacity, the resistance of R_{05} , and the filter. Input capacity, C_{in} , which consists also of the capacity of the input signal cable, tends to improve the CMRR by equalizing the normal-mode inputs so far as ac is concerned. CMRR is inversely proportional to the value of

R_{05} . As the value of R_{05} is reduced, I_H approaches I_L and the amount of common-mode conversion to normal-mode is consequently reduced. Filtered operation increases the CMRR as shown in paragraph 1-5 of the specifications. Theoretically, the filter would add 60 db to the unfiltered CMRR specification; however, because the guard is not a perfect shield, some common-mode currents are developed within the instrument and the CMRR is degraded accordingly.

2-33. The guarding and shielding employed in the Model 8350A provide means for effectively making Z_1 very large, thereby reducing E_{R02} to an acceptable level for reasonable values of R_{02} and consequently greatly enhancing CMRR. Z_1 is effectively increased by forcing the common-mode source to drive the guard shield to a potential equal to that on the internal signal return (See Figure 2-6). Under these conditions, there will be a small constant potential across the terminals of Z_1 , no current will flow through R_{02} and Z_1 , and consequently E_{R02} will nearly equal zero volts.

2-34. In Figure 2-6, Z_2 is placed directly across E_{CM} . Under some circumstances, where E_{CM} cannot be conveniently loaded with Z_2 , a guard driver may be used, as shown in Figure 2-7.

2-35. RADIATED NOISE

2-36. Another source of error which is often encountered is that of unequal noise induction in the unshielded input leads. The effective magnitude of this error is dependent on the following:

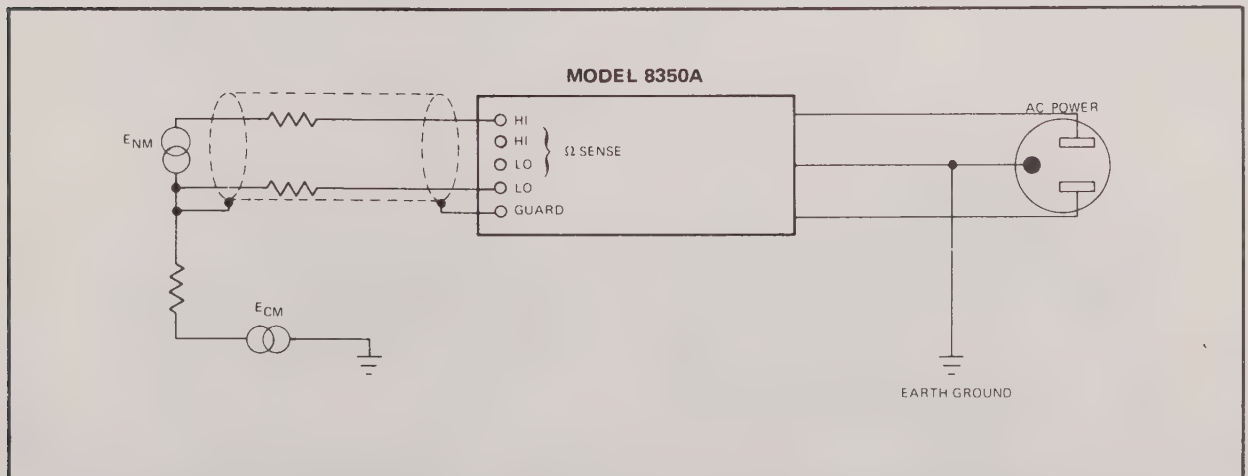


Figure 2-6. CONNECTIONS FOR DRIVING THE GUARD FROM THE COMMON-MODE SOURCE.

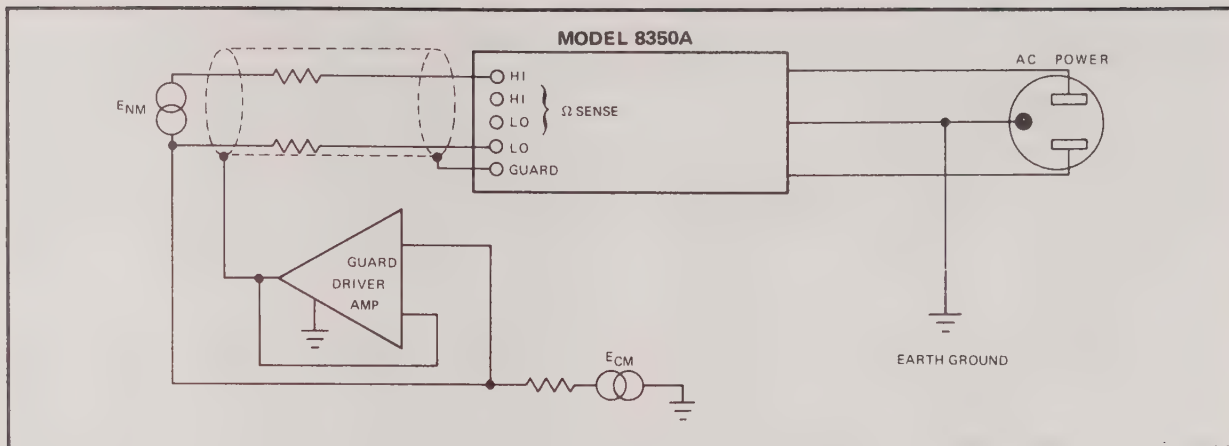


Figure 2-7. USING AN EXTERNAL AMPLIFIER TO DRIVE THE GUARD

- a. Value of R_{O1} and R_{O2} (source impedance).
- b. Length of input leads.
- c. Strength of interfering field.
- d. Frequency of interfering field.
- e. Instrument input impedance.
- f. Instrument input filter.

2-38. SUGGESTIONS FOR USING THE GUARD

2-39. Non-floating measurements will likely be the usual case. Under these conditions, it is satisfactory to strap the front panel GUARD terminal to the LO input terminal using the shorting link provided.

CAUTION!

If guarded measurement is not needed, the GUARD terminal should be connected to the LO input terminal at the front panel to preclude possible damage to the instrument.

2-37. The guarding and shielding techniques shown in Figures 2-6 and 2-7 are of considerable importance in reducing these errors, assuming that the noise does not originate in the source itself. Further improvement, however, may be obtained by using guarded or shielded cable terminations as shown in Figure 2-4.

2-40. Figure 2-8 shows two methods for connection of the guard terminal when making ohms measurements. Figure 2-8A shows proper guard connections for 2-terminal resistance measurements when signal leads are short and Figure 2-8B shows proper guard connections for 4-terminal

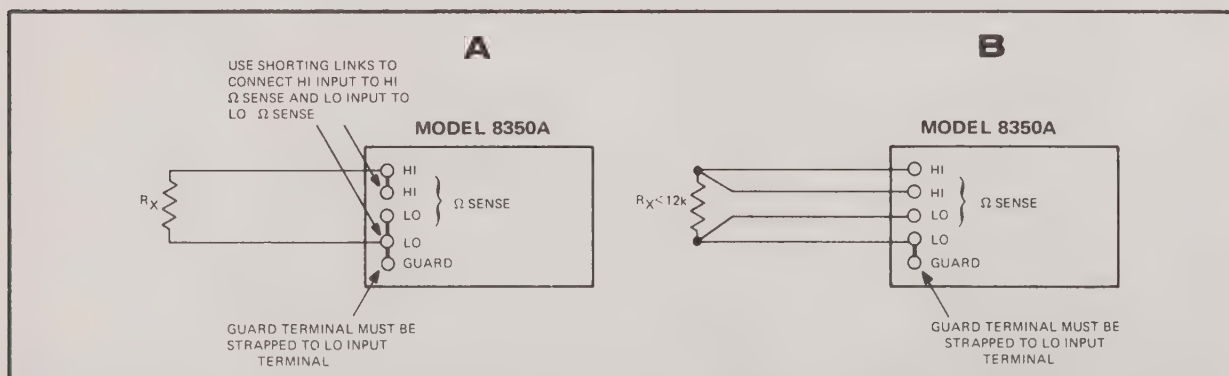


Figure 2-8. PROPER GUARD CONNECTIONS FOR (A) 2-TERMINAL Ω MEASUREMENTS WHEN SIGNAL LEADS ARE SHORT AND (B) 4-TERMINAL Ω MEASUREMENTS WHEN $R_X < 12k$.

resistance measurements when $R < 12k$ (when $R < 12k$, induced noise is generally insignificant but lead resistance can become a significant error).

2-41. In general guarded voltage and resistance measurements will be necessary under the following conditions:

- a. When long signal leads are used and source impedance is high.
- b. When the system is operating in the presence of high level radiated noise. The most common example is stray fields at power line frequency.
- c. When floating measurements are made and the common mode voltage is a high potential, high frequency, or both.

2-42. Rack Mounting

2-43. Rack mounting procedures are illustrated in Figures 2-9 and 2-10.

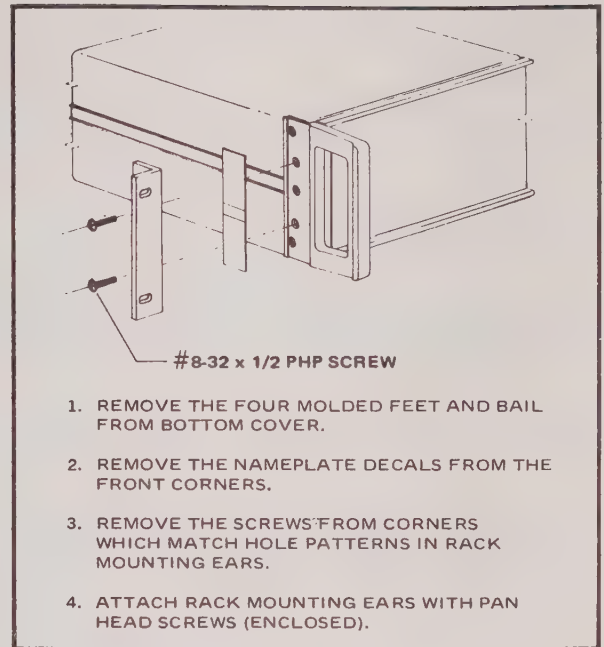


Figure 2-9. RACK MOUNTING EARS

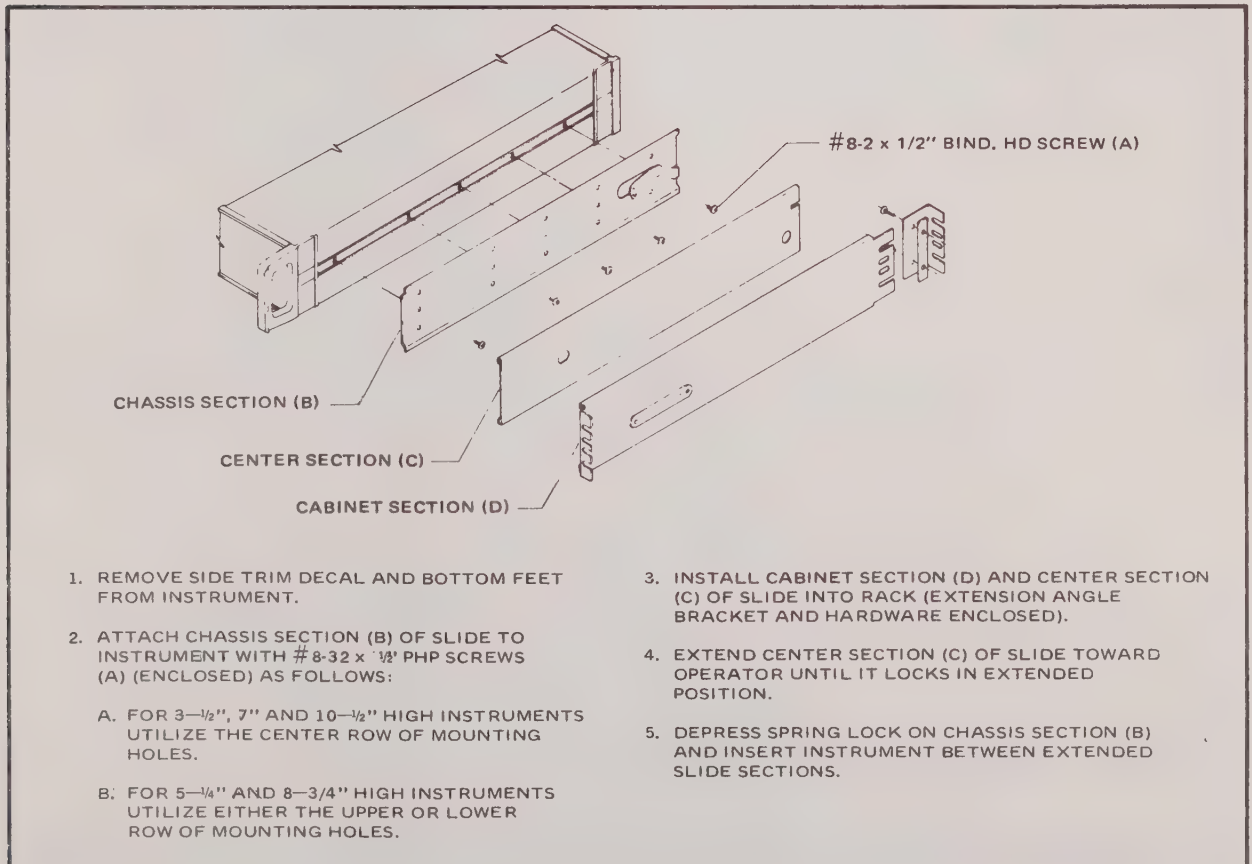


Figure 2-10. RACK MOUNTING SLIDES

Section 3

Theory of Operation

3-1. INTRODUCTION

3-2. This section describes the theory of operation of the Model 8350A Digital Multimeter. In the general discussion, the functional interaction of circuits and groups of circuits, as depicted in the accompanying simplified drawings, is examined. Component references and signal designations which appear on the simplified diagrams of actual instrument circuits correspond to those on the schematics.

The detailed circuit description is keyed to the instrument schematics, which are located at the back of the manual.

3-3. GENERAL**3-4. System Description**

3-5. In the Model 8350A Digital Multimeter, Figure 3-1, the buffer functions as an inverting unity-gain voltage

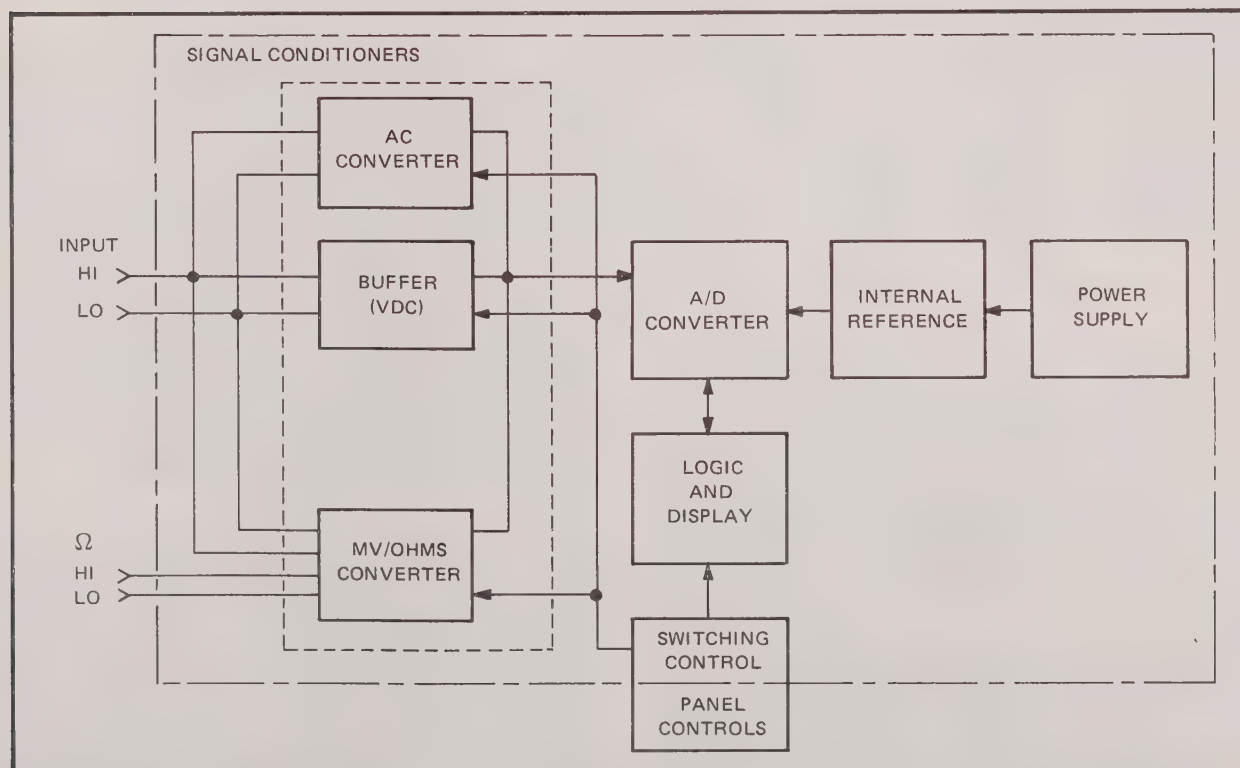


Figure 3-1. MODEL 8350A SYSTEM BLOCK DIAGRAM

amplifier. Its primary function is to provide an impedance conversion between the signal source which is being measured and the A/D converter input. The A/D converter accepts the buffer output, determines the polarity of the voltage, and converts the voltage into a binary coded decimal (BCD) output. The display circuitry accepts the BCD output of the A/D converter and displays the digits serially in a readout consisting of six neon indicator tubes. Timing and control of all system events is provided by the logic and control circuitry. The power supply produces the system operating voltages including the internal reference.

3-6. The AC converter converts input ac voltages, in four ranges, to a full-scale voltage of 12 volts dc (including 20% overrange) for measurement by the A/D converter. The Millivolt/Ohms converter converts input dc voltages in the range of 0 to 1000 millivolts to levels suitable for driving the A/D converter. In the ohms mode, the Millivolt/Ohms converter produces an output that is a direct analog of the unknown resistance and is of proper level to drive the A/D converter. Figure 3-2 shows the functional arrangement of the buffer, AC converter and Millivolt/Ohms converter in each of the DVM operating modes.

3-7. Buffer

3-8. The principal parts of the buffer are a 10 megohm input divider, which scales the dc input voltages to ± 12 volts full scale, a high gain FET input non-inverting opera-

tional amplifier (A1) which operates into a filter network, and a second operational amplifier (A2 which is connected inside its own feedback loop to provide an inverted gain of about 2.0. The basic buffer diagram is shown in Figure 3-3.

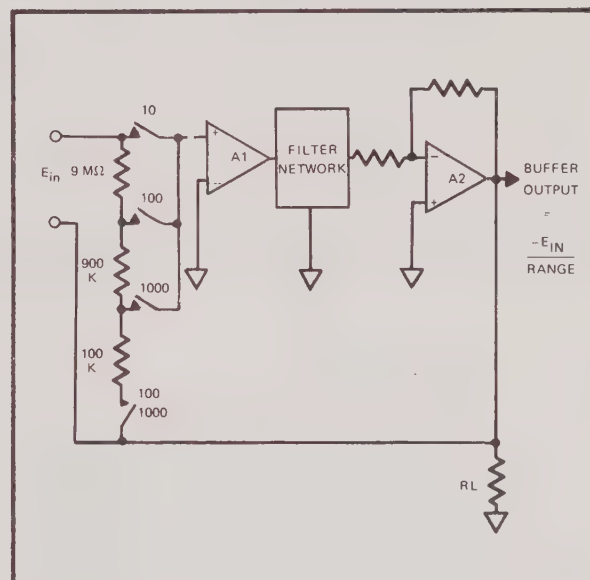


Figure 3-3. BUFFER BASIC DIAGRAM

3-9. Assume for explanation purposes that a positive voltage is placed across the input terminals. The voltage will be applied through the appropriate range switch to the input of A1. Since A1 is a high gain operational amplifier with its inverting terminal grounded, the positive input will produce a large in-phase signal at the amplifier output. When the positive output of A1 is applied through the filter network to the input of A2, A2 will be driven negative. The magnitude of the output of A2 will be determined solely by its input, which is in turn determined by the input to A1. The input of A1 will be at virtual ground and practically no current will flow from the source because of the high impedance FET input. Consequently, the output of A2 can only go to $-E_{in}$ with respect to analog common.

3-10. In addition to providing impedance buffering, the buffer also contains circuitry which is used to filter the input signal. The simplified diagram in Figure 3-4 shows the addition of the filter and input limiting circuitry to the basic buffer diagram. The notch filter provides 60 Hz filtering and the low-pass filter adds two additional poles, effective at 30 Hz. A graph of signal transfer versus frequency is shown in Figure 3-5. As shown in the graph, the rejection of ac signals having frequencies of 50 Hz and above is greater than 60 db at the instrument input.

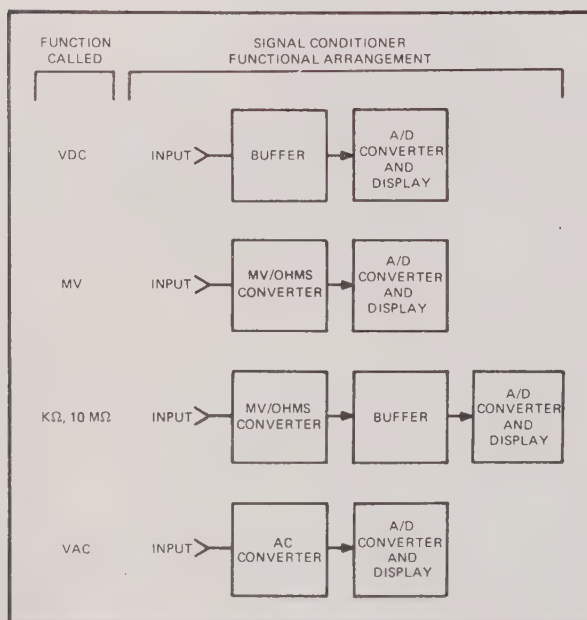
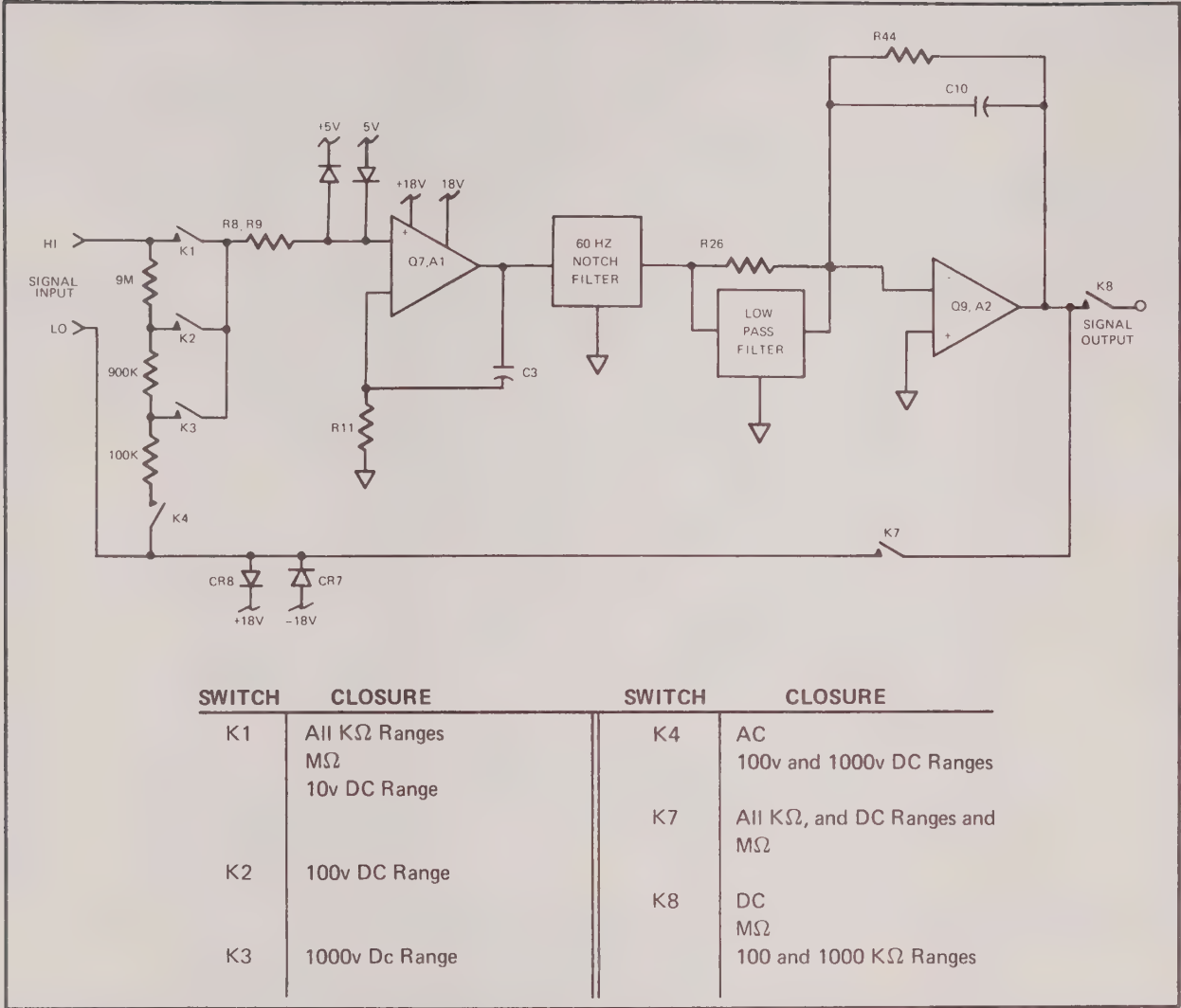


Figure 3-2. SIGNAL CONDITIONER FUNCTIONAL ARRANGEMENT.



SWITCH	CLOSURE	SWITCH	CLOSURE
K1	All KΩ Ranges MΩ 10v DC Range	K4	AC 100v and 1000v DC Ranges
K2	100v DC Range	K7	All KΩ, and DC Ranges and MΩ
K3	1000v Dc Range	K8	DC MΩ 100 and 1000 KΩ Ranges

Figure 3-4. BUFFER SIMPLIFIED CIRCUIT DIAGRAM

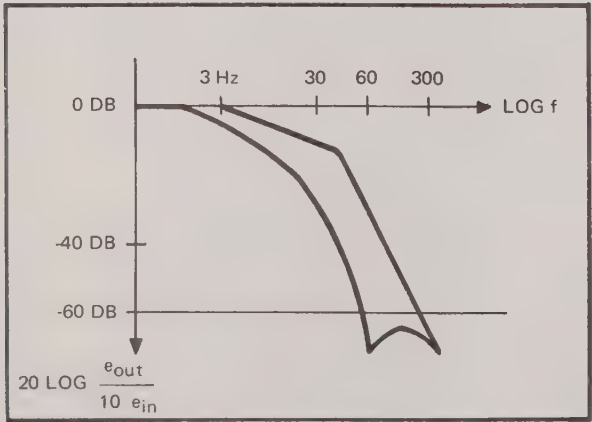


Figure 3-5. FILTER TRANSFER FUNCTION

3-11. Limiting circuits are provided at the input of A1 so that ± 1100 volt inputs will not damage the buffer on the 10 and 100 volt ranges. VDC, MVDC, VAC, K ohm and 10M ohm switches together with associated relays and relay drivers are mounted on the buffer board. These circuits are connected via control lines to the instrument logic and to respective signal conditioners.

3-12. AC Converter

3-13. The AC converter is divided into two major parts as shown in Figure 3-6: a wide band operational rectifier circuit where the ranging is accomplished, and a dc difference (or subtracting) amplifier/integrator to filter and amplify the rectifier output. The dc amplifier also pro-

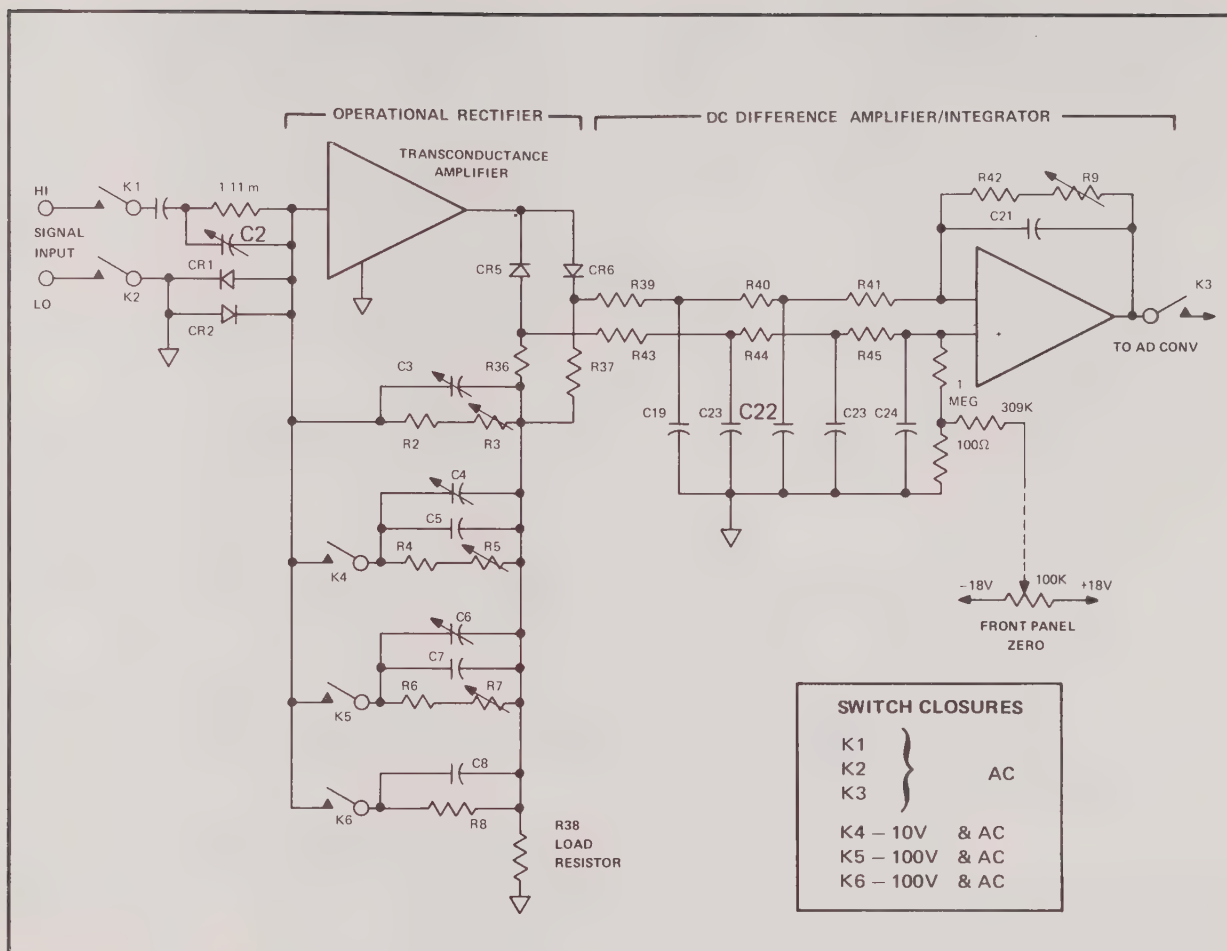


Figure 3-6. BLOCK DIAGRAM AC CONVERTER

vides the low source impedance required by the A/D converter.

3-14. The operational rectifier circuit consists of an inverting transconductance amplifier and load resistor with negative feedback arranged to provide a loop gain of about 5×10^3 at mid band. The feedback is changed with reed switches for range purposes. The input resistor is 1.11 megohms and this value, shunted by the 10 megohm input divider (located on buffer board), provides 1 megohm input impedance at the Model 8350A input terminals. A symmetrical half-wave rectifier placed between the amplifier and load resistor develops equal positive and negative dc voltages proportional to the amplifier output current. At full scale this current is near 2 milliamps. The two outputs have waveforms as shown in Figure 3-7.

3-15. The dc-difference amplifier/integrator filters the waveforms shown in Figure 3-7 and amplifies the dc dif-

ference between them by about ten times for measurement by the A/D converter. Three sections of filtering reduces the ac voltage to a ripple level which cannot be observed on the readout when the input is at full scale and above a frequency of 100 Hz. Below 100 Hz a few digits respond to the ripple. At 50 Hz the readout excursions are typically less than $\pm 0.01\%$ of reading and at 30 Hz are within $\pm 0.05\%$ of reading.

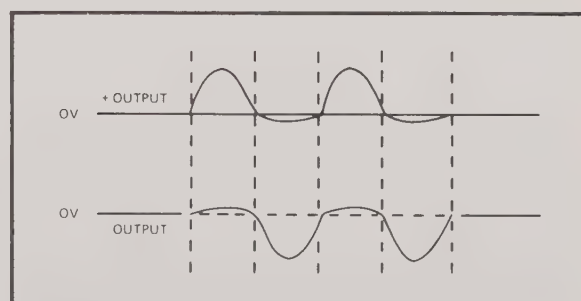


Figure 3-7. RECTIFIER OUTPUT WAVEFORMS

3-16. MV/Ohms Converter

3-17. The MV/Ohms converter may be thought of as two separate converters. One is a chopper-stabilized amplifier which provides dc amplification of the unknown voltage to levels suitable for driving the A/D converter. The other is a precision current ladder which, in conjunction with the buffer amplifier, provides a known current through the

unknown resistor at the input terminal of the MV/Ohms converter. Simplified diagrams of the two converters are shown in Figure 3-8.

3-18. MILLIVOLTS CONVERTER

3-19. The millivolt amplifier can be considered to be a high dc gain operational amplifier utilizing potentiometric

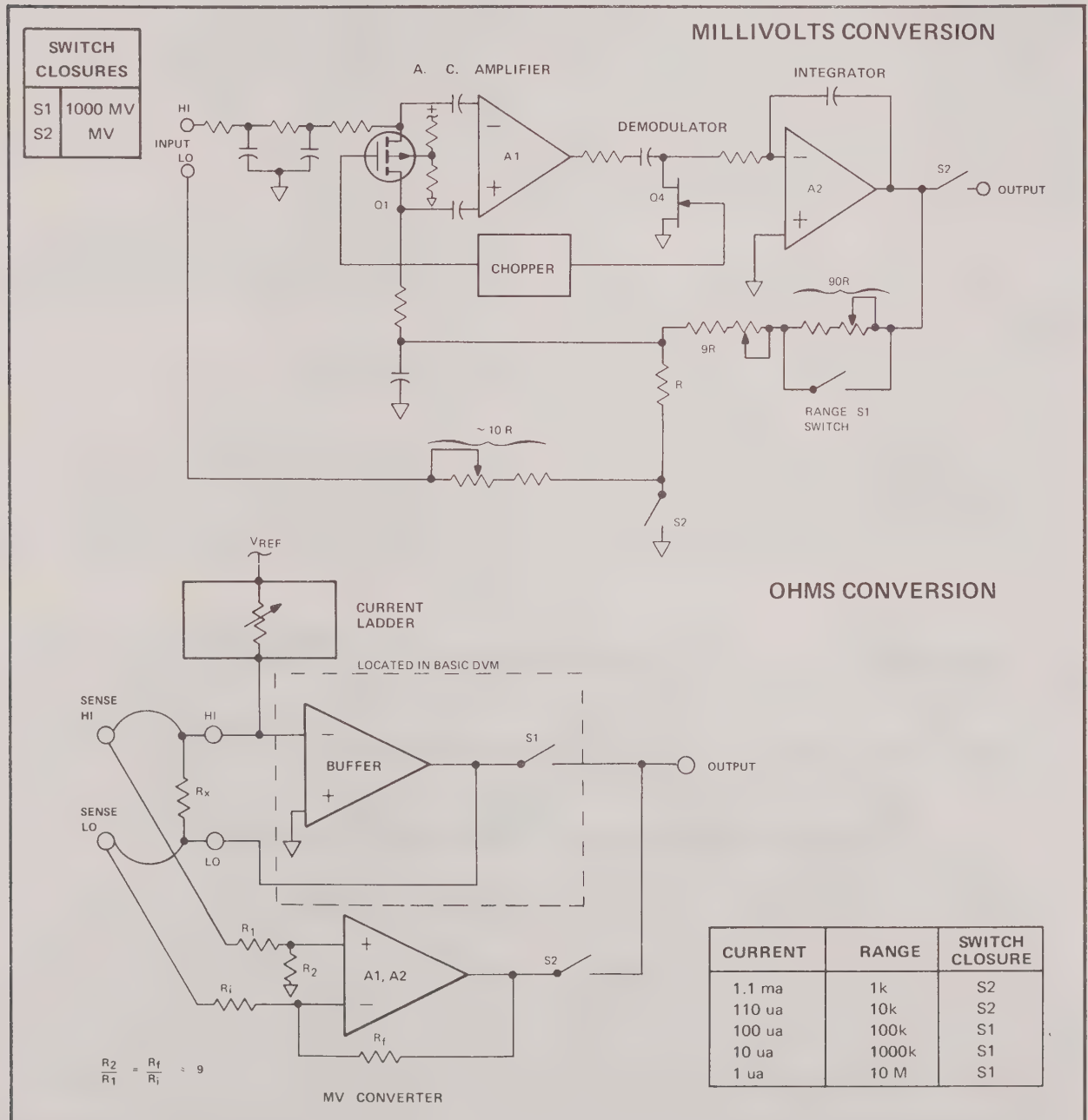


Figure 3-8. SIMPLIFIED DIAGRAM OF MV/OHMS CONVERTER CIRCUIT ARRANGEMENT FOR EACH OPERATING MODE.

feedback to provide programmed gains of +10 or +100 and very high input impedance at dc. The A/D converter follows the millivolts converter and digitizes its amplified analog output which represents the input signal to the millivolts converter.

3-20. A MOSFET chopper is used across the summing junctions of the operational amplifier. The signal developed by the chopping action is amplified and applied through a capacitor to a half-wave synchronous demodulator. The demodulator output is applied to a high gain (at dc) operational amplifier connected as an integrator. The integrator output is applied to the MOSFET chopper in such a manner as to ensure negative feedback. The RC network at the input provides filtering to prevent beat frequency products at the amplifier output and to provide balanced ac impedance for the chopper.

3-21. The use of the MOSFET chopper allows spikes developed due to capacitive coupling from gate drive to channel to become a common mode signal for a high CMRR operational amplifier. Balanced AC impedances at the chopper provide a cancellation effect on the offset current and voltage which results from the capacitive spike. The net result is a chopper amplifier capable of operating at a fairly high frequency with small voltage and current offsets and with spikes of low enough value to keep the ac amplifier from saturating. The above operation is achieved without adjustments for spike compensation.

3-22. OHMS CONVERTER

3-23. The current ladder is connected to the buffer and millivolts converter as shown in Figure 3-8. The inverting terminal of the buffer amplifier is held very near analog common by the feedback connection of the unknown resistance. Because the inverting terminal is held near ground and because the input current to the buffer is small, the current through the unknown resistor is set by V_{REF} and the selected current-ladder resistor. For the three upper kilohm ranges, the output of the buffer is connected to the A/D converter. Thus, since the A/D converter digitizes 11.9999V as full scale, that voltage must represent full scale on the 10 megohm, 1000 kilohms, and 100 kilohm ranges where 1199.99 kilohms and 119.99 kilohms represent full scale respectively. For the 1 and 10 kilohm ranges, small full scale voltages are used to minimize power dissipation in the unknown resistor. Thus, on these two ranges, the millivolts converter is used to amplify the voltage across the unknown resistor and present the amplified voltage to the A/D converter.

3-24. In addition to providing small full-scale measurement voltages in the lower two resistance ranges, use of the millivolts converter allows a modified four-terminal resistance measurement to be made. The term modified four-terminal is used because the technique employed requires a small current in one of the sense lines that would not be present in a true four-terminal resistance measurement. The sense current magnitude is determined by the voltage impressed on the unknown resistor divided by R_i . The error contributed by the sense current can be expressed as the ratio of the resistance in the sense line to R_i ; i.e., if the sense line resistance is 1 ohm, then the error due to the sense current can be computed roughly as follows:

$$\text{Error} = \frac{1.0 \text{ ohm}}{R_i} = \frac{1.0 \text{ ohm}}{100K \text{ ohm}} = 10^{-5} \text{ or } 10 \text{ ppm of reading}$$

3-25. If a two terminal reading were made at the 1 kilohm level with a 1.0 ohm resistance in the hook-up wires, the error would be 1000 ppm. The improvement in performance using the modified four-terminal measurement is obvious.

3-26. A/D Converter

3-27. The A/D converter employs the unique recirculating remainder (R^2) A/D conversion technique developed by Fluke. A simplified diagram of the basic A/D conversion technique is shown in Figure 3-9. Accompanying the diagram is a chart showing the sequence of operation for an input of -6.3524 volts.

3-28. The A/D converter digitizes the input serially in five 3-millisecond time periods, A through E, with each period divided equally into digitizing and display periods, 1 and 2. At the start of the measurement sequence, period A1, the A/D converter samples the -6.3524 volt input. Then the analog output voltage from the X10 amplifier causes the comparator to operate the current controlled oscillator (CCO), whose pulses are counted by the digits counter. When the total pulse count equals the most significant digit of the input or "6," the CCO stops. The ladder produces a series of current steps, which correspond to the counter output. The remainder of 0.3524 volts is amplified by the X10 amplifier and held in the sample and hold capacitor, C1. The display circuitry decodes the counter output and displays the "6" in period A2. At the beginning of period B, the -6.3524 volt input is disconnected from the input of the A/D converter and the 3.524 volt output of the sample and hold circuit is digitized and displayed as the new input. Successively, the remainders of 5.24, 2.4, and 4 volts are digitized and displayed in the same manner. Although the five digits are digitized and dis-

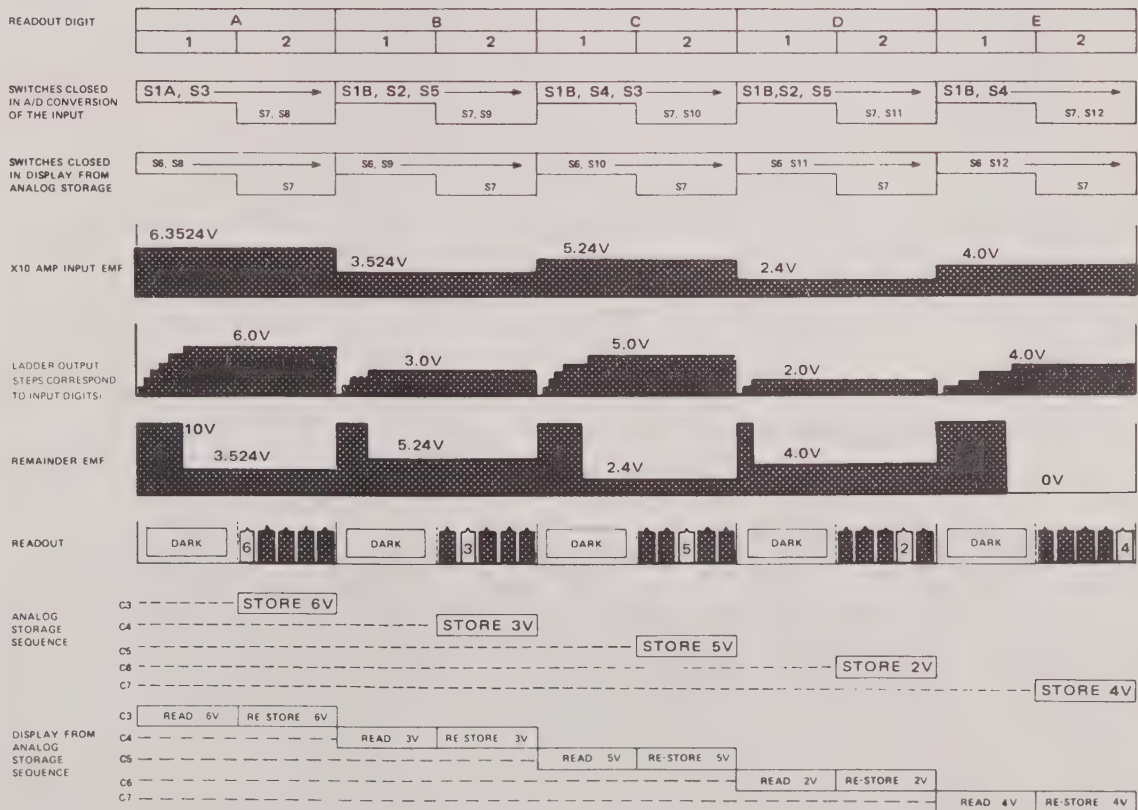
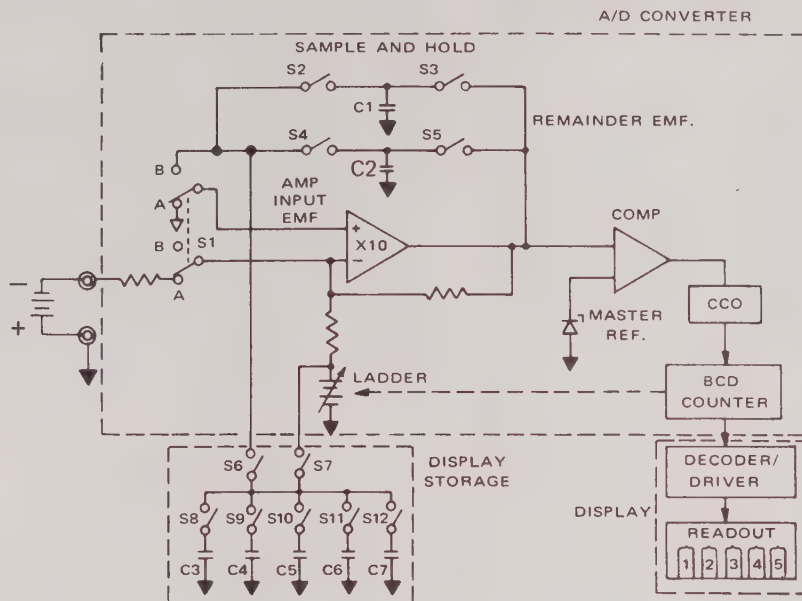


Figure 3-9. RECIRCULATING REMAINDER A/D CONVERSION

played one at a time, the process proceeds at a sufficiently high rate of speed so that the display appears continuous to the eye.

3-29. The input voltage is sampled at a fixed rate of 4 per second. Since it only requires 18 milliseconds to digitize the input, a display storage circuit is provided which stores voltages representing each of the five digits on each of five capacitors. This stored information supplies the A/D converter input during the remaining digitize/display periods until the DVM is ready to sample the input voltage again. The period when the actual input is sampled and

digitized is known as the measurement cycle, and the period when the A/D converter reads out of storage is known as the storage cycle.

3-30. The A/D converter has two basic operating modes. It is connected as an operational amplifier during the first period of the measurement cycle, and it is connected as a voltage follower during the remaining four periods of the measurement cycle. The simplified diagram of Figure 3-10(A) shows the circuit arrangement for measurement of the first digit (6) of a -6.3524 volt input. The amplifier is satisfied by two feedback loops. The loop consisting of

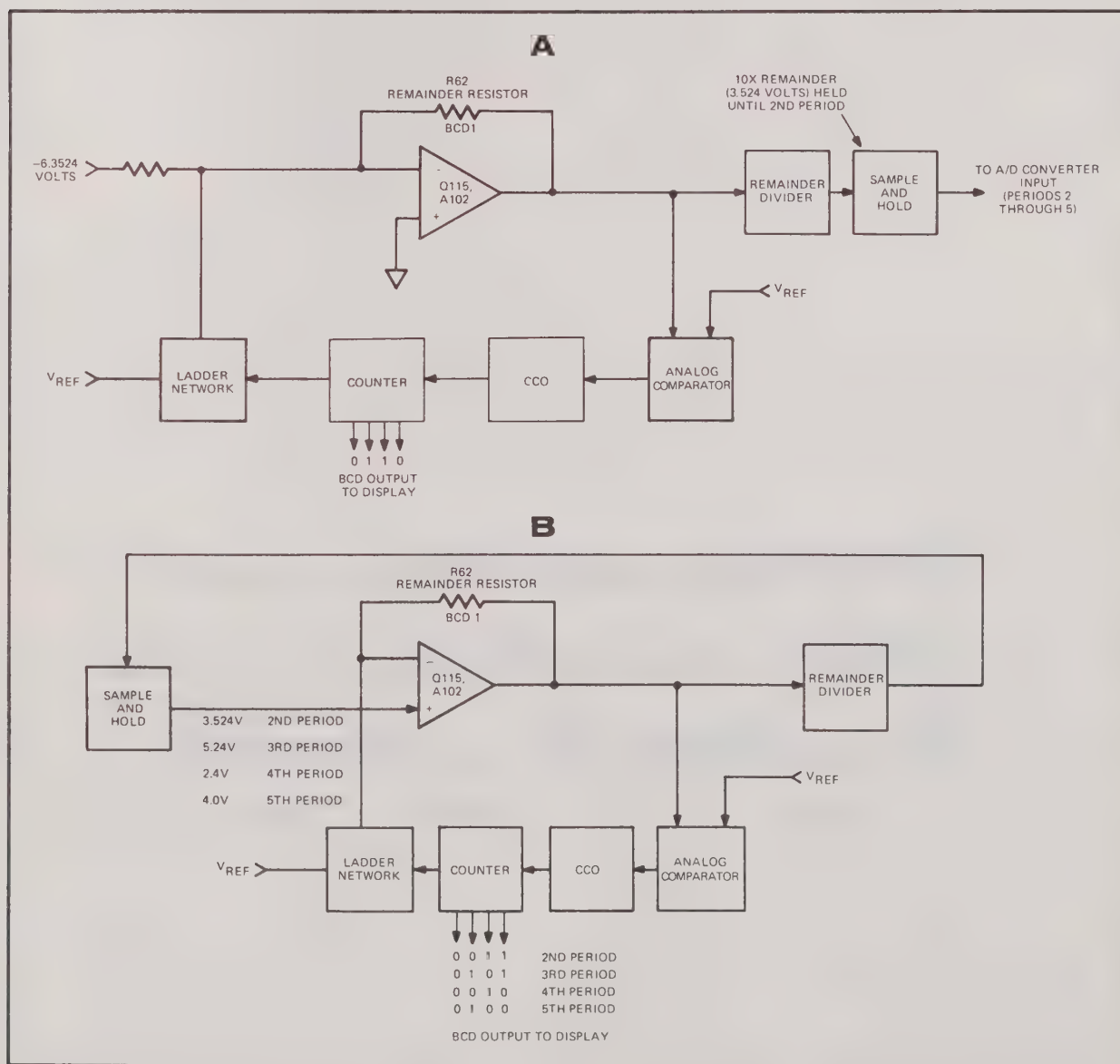


Figure 3-10. A/D CONVERTER CIRCUIT ARRANGEMENT FOR DIGITIZING AND DISPLAYING
(A) FIRST DIGIT AND (B) SECOND THROUGH FIFTH DIGITS

the CCO, counter, and ladder is activated whenever the amplifier output exceeds V_{REF} , while the remainder resistor feedback loop satisfies the amplifier for all amplifier outputs less than V_{REF} . The sum of the two feedback currents and the input current flowing into the summing junction at the amplifier input result in amplifier balance. After a short interval, during which time the amplifier is allowed to settle, the "6" is displayed and the amplified remainder is applied to the input of the amplifier, now connected as a voltage follower, and is digitized and displayed as the new input

signal. Succeeding remainders are applied, in turn, through the sample and hold circuit to the amplifier input, until the entire -6.3524 volt input has been digitized and displayed.

3-31. The A/D converter together with associated circuitry is shown in more detail in the simplified diagram of Figure 3-11. The inverting amplifier is an inverting operational amplifier consisting of input resistor R2, amplifier Q1, A1 and feedback network CR1, CR2, and R3. The output of A1 drives the polarity detector, which operates the positive and negative (plus and minus) gates. The inverting amplifier together with the polarity detector ensures that the A/D amplifier is always presented with a

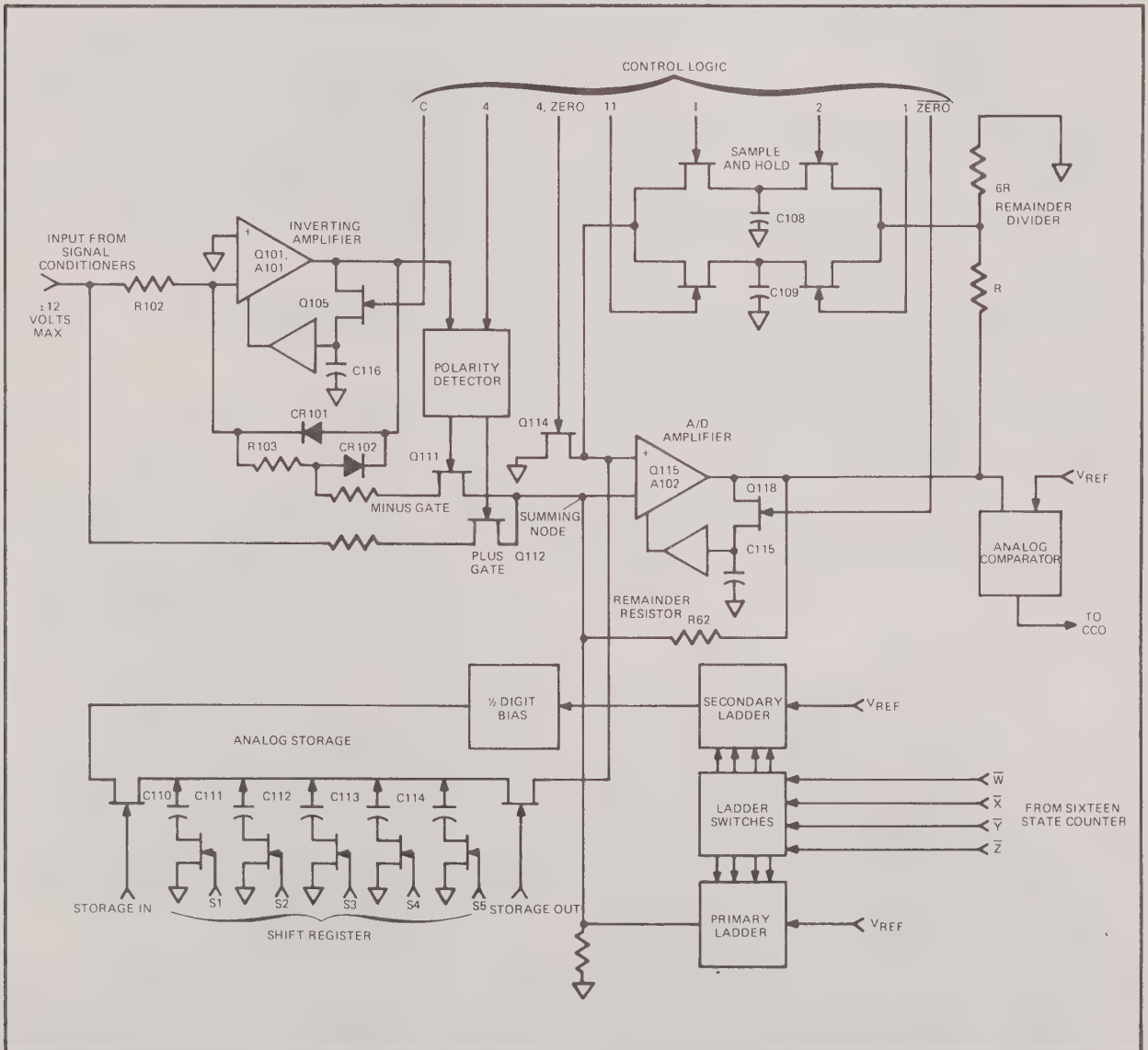


Figure 3-11. A/D CONVERTER SIMPLIFIED CIRCUIT DIAGRAM

negative input. For example, a negative instrument input would appear at the A/D converter input as a positive voltage (because of inversion in the buffer). The positive input would be inverted in the inverting amplifier and the polarity detector would turn on the minus gate. If the instrument input were positive, the inverting amplifier would produce a positive output and the polarity detector would turn on the plus gate. During the periods when the A/D amplifier input is supplied by the sample and hold circuit, the plus and minus gates are turned off by a logic signal applied to the polarity detector. Switch Q114 is also turned off by a logic signal, thereby enabling the output of the sample and hold circuit to be applied to the A/D amplifier. The half-digit bias circuit adds the voltage equivalent of a half digit to the charge stored on each display storage readout by compensating for the effects of voltage decay in the storage circuit.

3-32. In addition to the five periods required for digitizing and displaying the input signal, a sixth period, known as the zero period, is set aside for removal of the zero offset of the A/D amplifier. During the zeroing period, switch Q118 is turned on which connects the output of A102 to the zero holding capacitor C115; at the same time, the amplifier input is grounded. This operation places the offset of A102 across C115 and effectively removes it for the balance of the measurement cycle. The same zeroing operation is also performed on the inverting amplifier and occurs during a period in the measurement cycle when the amplifier is not being used. The complete sequence of operations for both measurement and storage cycles is shown in Figures 3-12 and 3-13. The various circuit arrangements of the A/D converter are summarized in Figure 3-14, which shows the simplified circuit for each operating mode in both measurement and storage cycles.

3-33. Logic and Control

3-34. The logic and control block diagram is shown in Figure 3-15. The 333 Hz master clock is the master timing reference for the instrument and is used throughout the logic and control circuitry. The six-state shift register, which is driven from the master clock, produces signals which establish the five digitize/display periods and the zero period of the A/D converter. The analog cycle control circuitry uses signals from the shift register and cycle-change circuitry to derive A/D control signals. The display section includes circuitry which controls the nine function/status indicators and the readout decimals, including two memory circuits which provide control of polarity and overload indicators. The 16-state binary counter is driven by the CCO. Counter outputs are applied to the ladder switches in the

A/D converter and to the decoder/driver, which outputs to five of the six readout tubes. Counter inputs include those from two catcher circuits. The 12's catcher stops the counter unconditionally whenever its count reaches twelve. The conditional 11's catcher stops the counter when its count reaches eleven if the instrument is in 10M ohm mode (if it is on the high range or if it is not autoranging). The manual and autorange circuits accept the manual and remote range signals and provide control of all instrument ranging. The cycle change circuitry establishes the measure and storage cycles. The timing diagram for the measure portion of the measure/store cycle of the instrument is shown in Figure 3-16.

3-35. Power Supply

3-36. Operating voltages for the Model 8350A are produced by a series of regulated supplies as shown in Figure 3-17. The +18 volt and -18 volt regulator outputs are used throughout the instrument as operating voltages. The +190 volt regulator output is used to power the readout tubes. The +5 volt regulator output is used to power the logic. The +7 volt regulator output is the master voltage reference for the instrument.

3-37. CIRCUIT DESCRIPTION

3-38. Buffer

3-39. INPUT RANGE DIVIDER

3-40. The input binding posts are connected across a three-position, 10-megohm range divider consisting of resistors R1 through R7 and resistor R54. The 100 volt and 1000 volt ranges are adjusted by potentiometers R4 and R6 respectively. Depending on the range selected, the divider scales the input voltage down by a ratio of 10, 100, or 1000 so that the divider output will always be 10 volts full scale or 12 volts including 20% overrange. The input resistance is 10 megohms on the 100 and 1000 volt ranges, but the contacts of relay K4 are open on the 10 volt range and the input resistance is limited only by the leakage resistance at the input terminals. The overload protection network, consisting of transistors Q5 and Q6 and diodes CR7 and CR8, limits the voltage at the input of Q7 so that overvoltage will not damage the instrument.

3-41. AMPLIFIER/FILTER

3-42. The input amplifier consists of Q7, a low-noise, low-drift FET pair operating in common-source configuration. Potentiometer R47 is the zero adjustment control which, in conjunction with resistors R13, R14, and R55, is

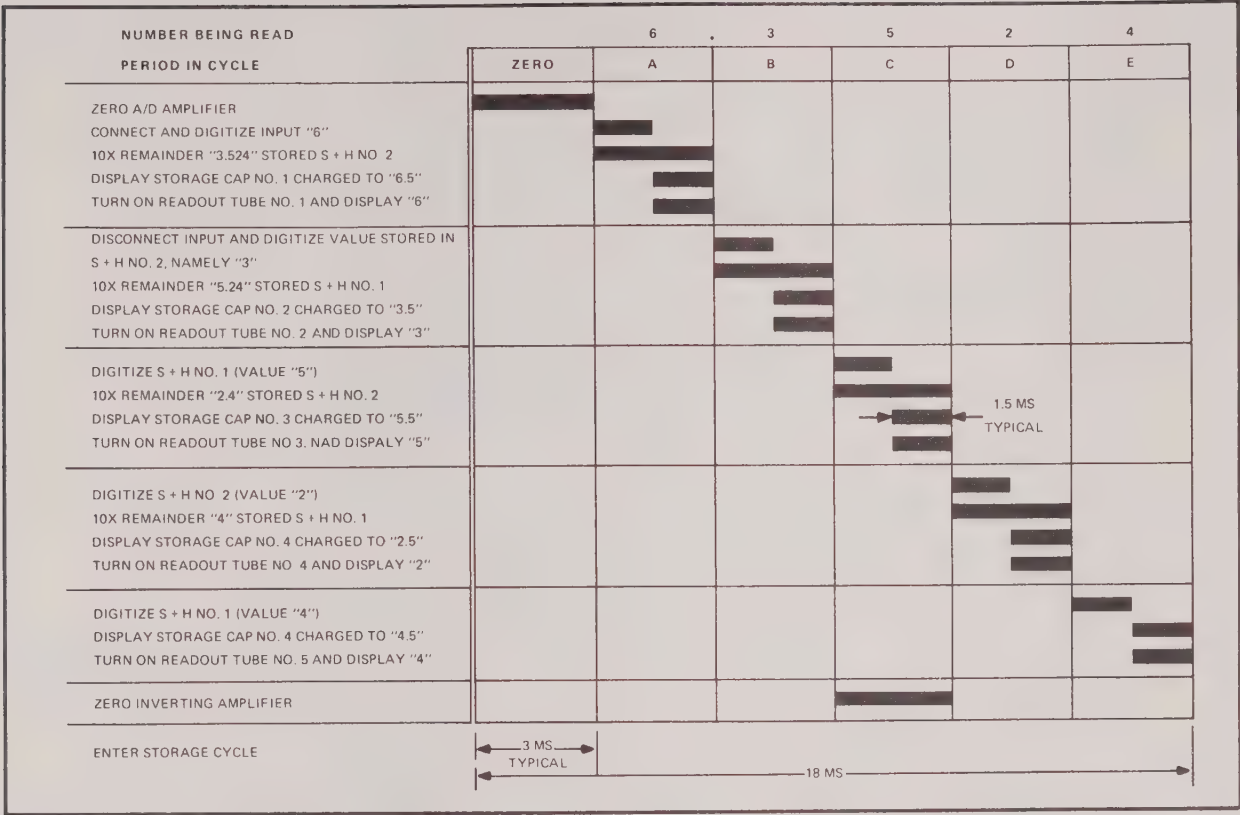


Figure 3-12. EVENT SEQUENCE – MEASUREMENT CYCLE

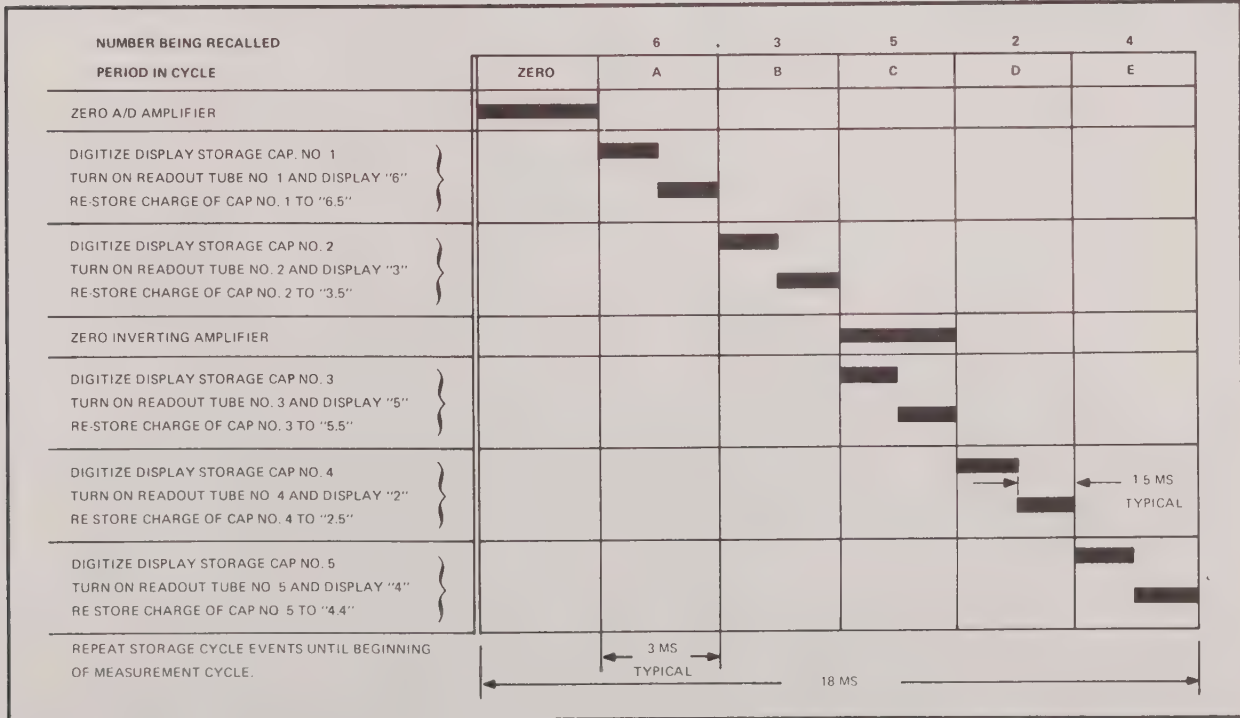


Figure 3-13. EVENT SEQUENCE – STORAGE CYCLE

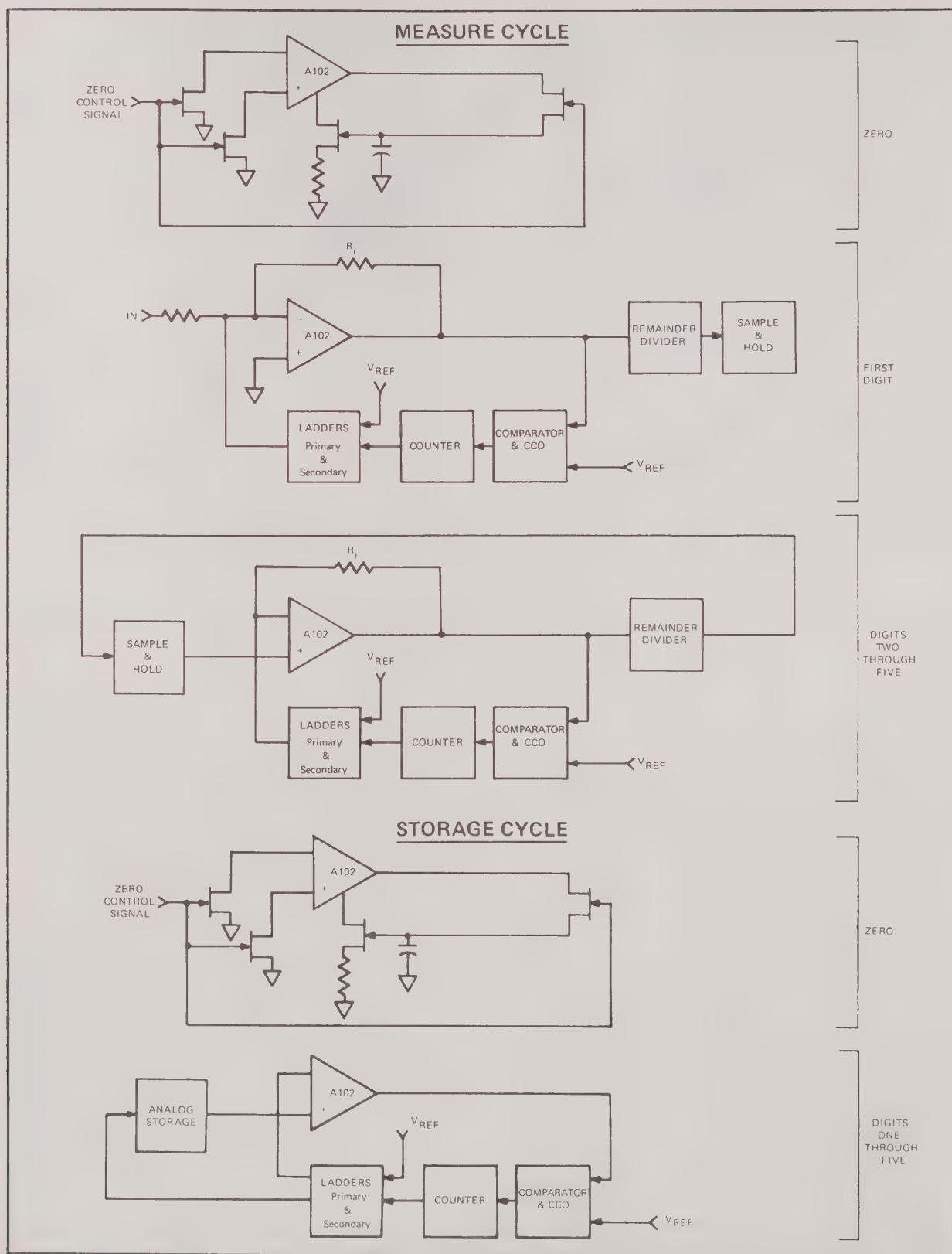


Figure 3-14. SIMPLIFIED A/D CONVERTER CIRCUIT ARRANGEMENT FOR EACH OPERATING MODE.

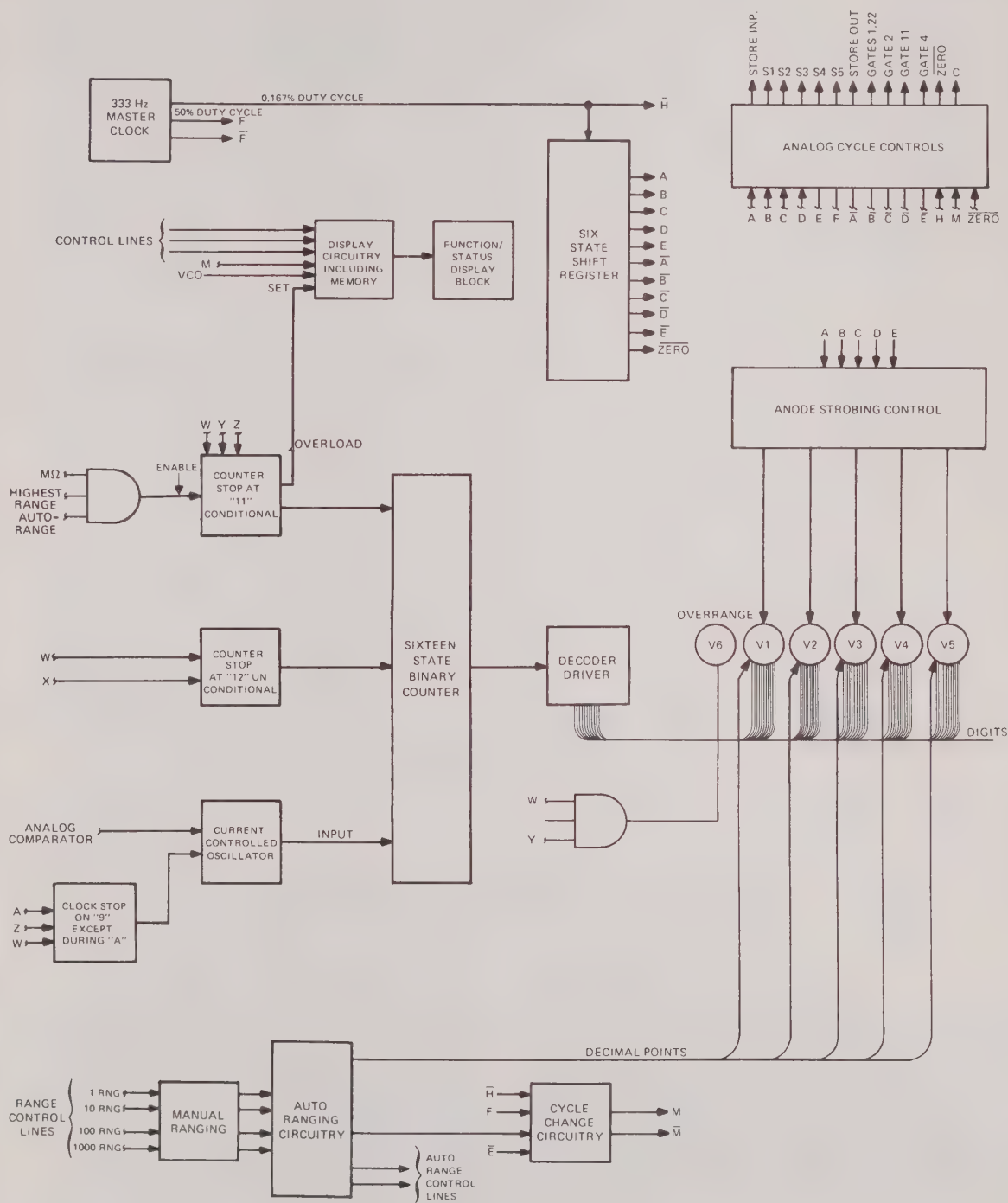


Figure 3-15. DVM LOGIC AND CONTROL BLOCK DIAGRAM

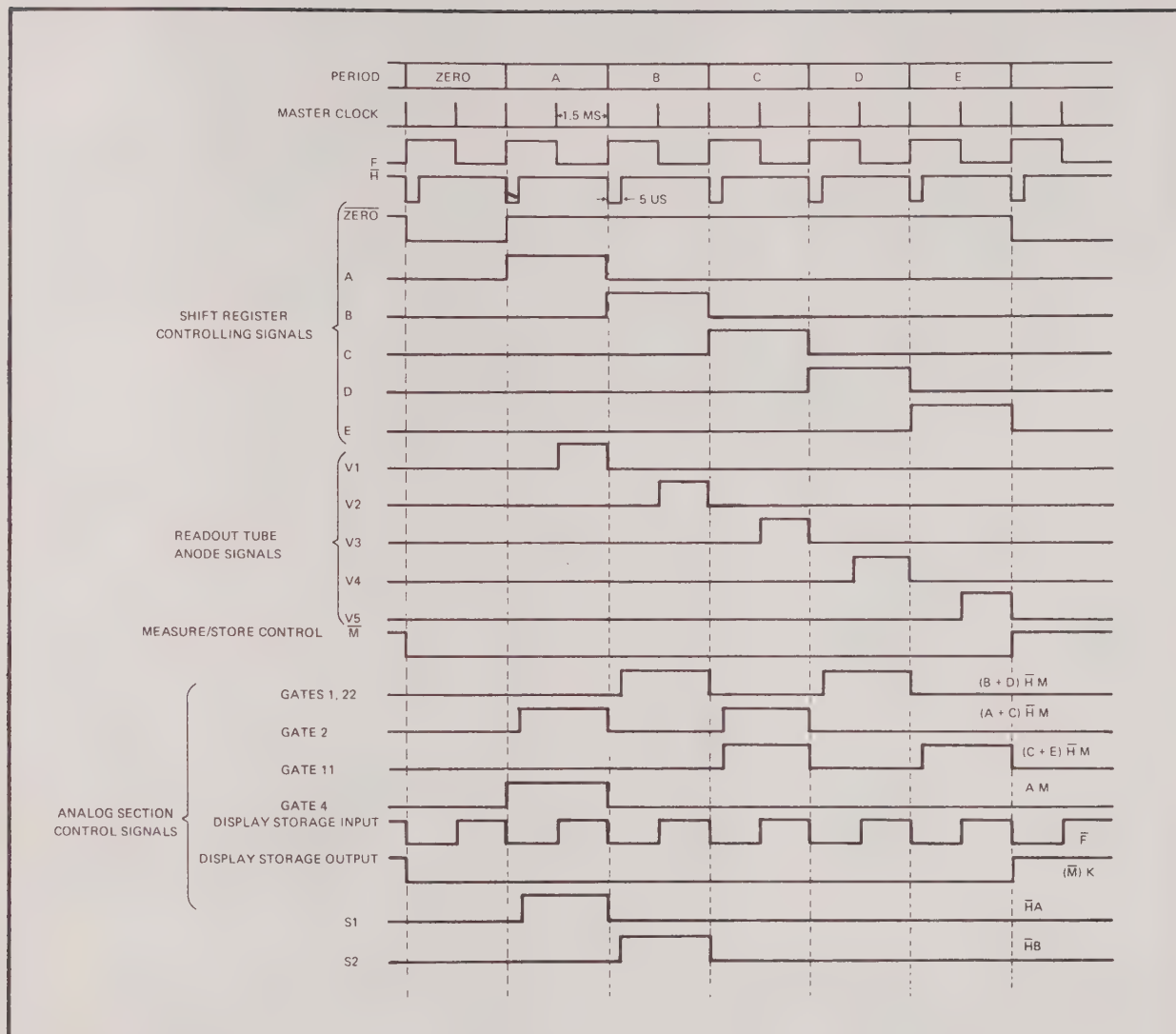


Figure 3-16. MEASUREMENT CYCLE TIME RELATIONS

used to reduce the initial offset of Q7 to zero. The output of Q7 drives A1, a high-gain, monolithic operation amplifier. The filter network consists of capacitor C3 and resistor R11, the notch filter, the low-pass filter, and capacitor C10 and resistor R44. FET Q8 provides an impedance transformation between the notch filter and the low-pass filter. The final amplifier stage consists of differential FET pair Q9 and operational amplifier A2.

3-43. SWITCHING

3-44. Switch block S1 includes all of the front panel function switches. Each of the front panel function switches is supplied with +5 volts dc which is applied

to control lines connected to function control and display circuitry in the logic section. The range relays are controlled by the range flip flops in conjunction with the manual and autorange circuitry which is located in the logic section. Figure 3-18 shows the control switching arrangement for the instrument.

3-45. AC Converter

3-46. OPERATIONAL RECTIFIER

3-47. Input FET Q1 functions as a source follower, while transistor Q2 provides a low impedance guard voltage which is used to bootstrap most of the capacity that other-

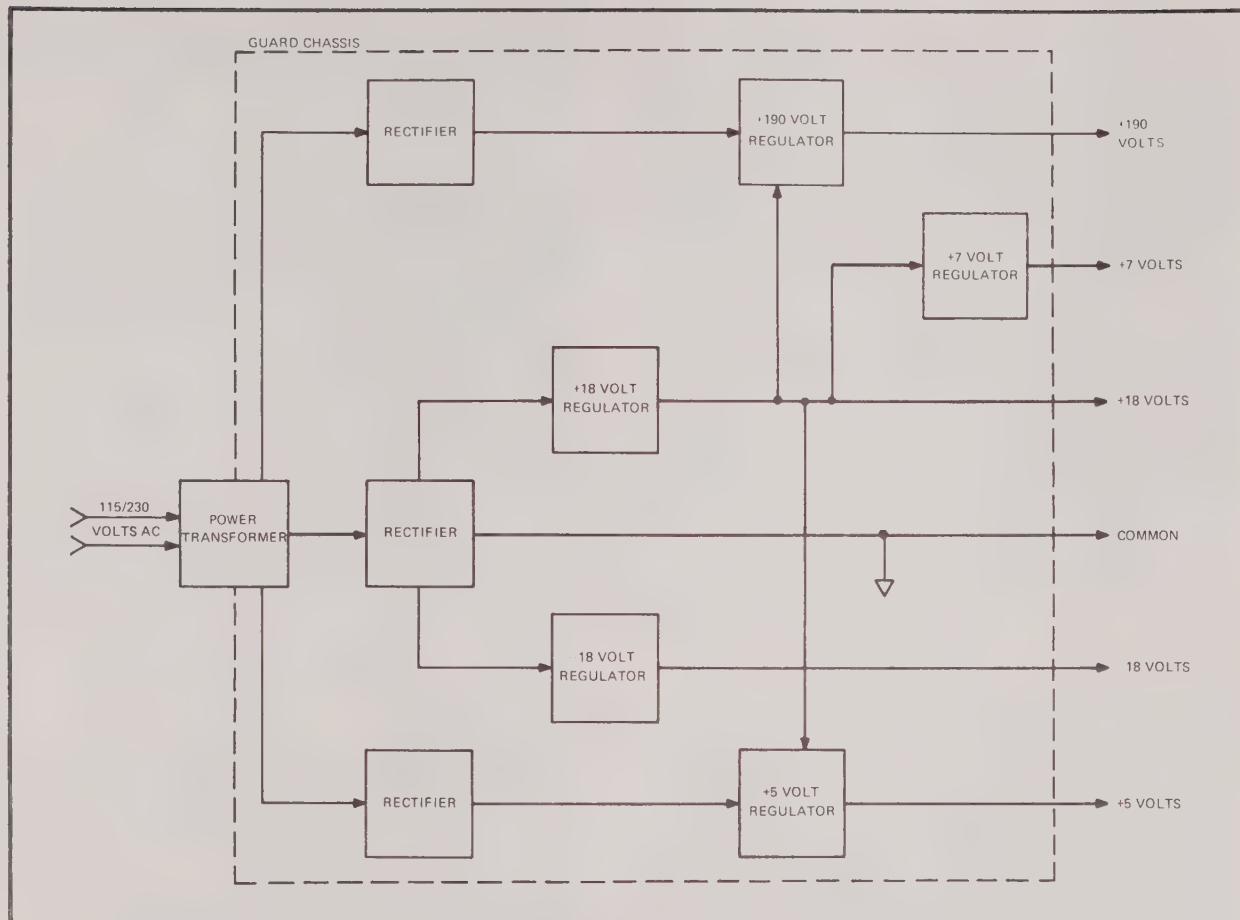


Figure 3-17. POWER SUPPLY BLOCK DIAGRAM

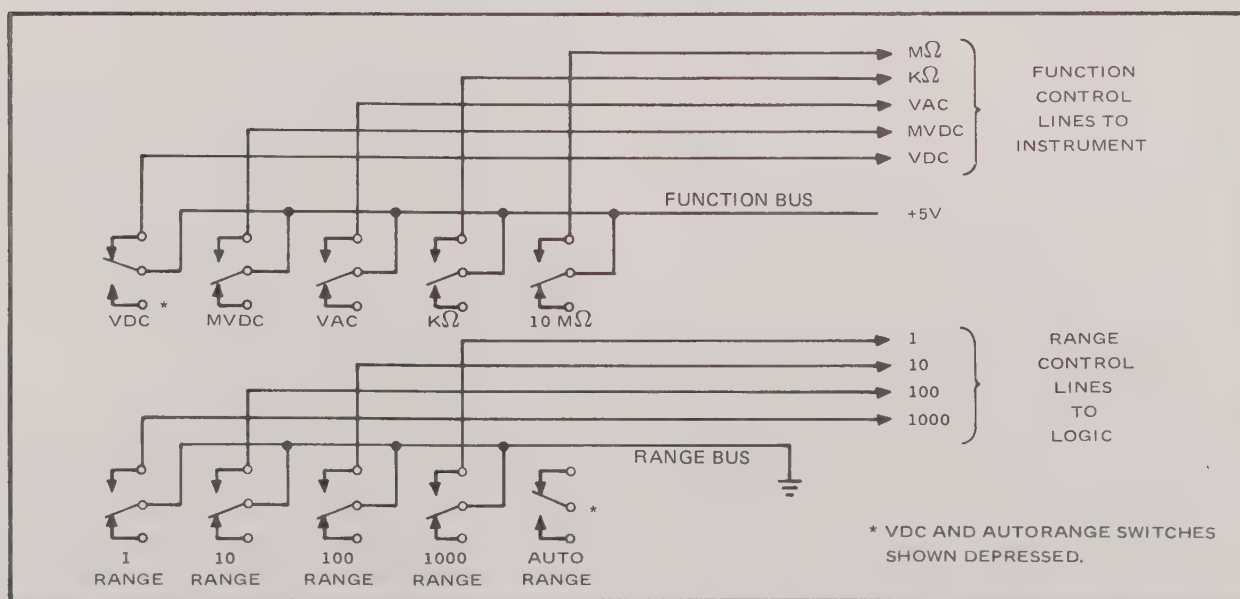


Figure 3-18. CONTROL SWITCHING CIRCUIT DIAGRAM

wise would appear between the FET gate and common. The first two differential pairs are in dual in-line package ICI. Together with Q4 and Q5, they develop the required gain. Transistors Q3 and Q6 function as current sources, with values such that clipping due to overload is symmetrical. Changes in capacitor charges are small and amplifier recovery time is minimized. Transistor Q7 compensates for capacitance losses in the diodes at low levels.

3-48. DC-DIFFERENCE AMPLIFIER/INTEGRATOR

3-49. The filter network, which provides the input to the amplifier/integrator, consists of resistors R39, R40, R41, R43, R44, R45 and capacitors C19, C20, C22, and C23. Capacitors C19 and C20 are matched with C22 and C23, respectively, to maintain good common-mode rejection. Transistor Q9 is a dual FET which functions as the input of the low drift dc amplifier. Further gain for the dc amplifier is provided by monolithic operational amplifier IC2, thereby producing a total loop gain at dc of about 5×10^5 .

3-50. RANGE AND FUNCTION CONTROL

3-51. The converter input and output relays, K1 through K3, are operated from the VAC control line. The range relays, K4 through K6, are operated by driver circuitry consisting of transistors Q10 through Q15 and associated components. The range control transistors accept the input from range flip flops, 18a and 18b, located in the DVM logic section, and perform the logic function associated with calling of the AC ranges.

3-52. Millivolt/Ohms Converter

3-53. AMPLIFIER

3-54. The input stage of the ac amplifier consists of differential stage Q2 and Q3 (see schematic at back of manual). The MOSFET chopper, Q1, is switched off and on at a 200 Hz rate by the squarewave signal applied to its gate. This modulates the input signal and produces a squarewave output signal to Q2 with an amplitude proportional to the amplitude of the loop error signal. The differential output of Q2/Q3 is amplified in A1 and applied to Q4, where it is demodulated. The demodulated output is applied to integrator A2. The 1000 MV and 100 MV adjustments, R32 and R28, are located in the negative feedback path. The chopper switching signal is produced by a multivibrator using transistors Q6 and Q7.

3-55. CURRENT LADDER

3-56. The current ladder consists of resistors R39 through R47 and resistor R58. The ladder is operated by

relays K5, K6, and K7, which are selected by appropriate function and range commands as shown in Figure 3-19.

3-57. RELAY DRIVERS

3-58. Relays K1 through K8, are operated by drive circuitry consisting of transistors Q8 through Q10, integrated circuit A3, and associated components. This circuitry accepts inputs from the function control lines and the range flip flops, 18a and 18b, in the DVM logic section and implements the logic functions of Figure 3-19 to operate the MV/Ohms Converter.

RELAY	LOGIC FUNCTION	FUNCTION PERFORMED
K1	MV	100MV, 1000MV
K2	$K\Omega \cdot a + MV$	$1K\Omega$, $10K\Omega$, 100MV, 1000MV
K3	$K\Omega + M\Omega$	$1K\Omega$, $10K\Omega$, $100K\Omega$, $1000K\Omega$, $M\Omega$
K4	$K\Omega \cdot a$	$1K\Omega$, $10K\Omega$
K5	$K\Omega \cdot a \cdot b$	$1K\Omega$
K6	$K\Omega \cdot (a + b)$	$1K\Omega$, $10K\Omega$, $100K\Omega$
K7	$K\Omega \cdot b$	$10K\Omega$, $1000K\Omega$
K8	$MV \cdot b$	1000MV

Figure 3-19. MV/OHMS CONVERTER RELAY FUNCTION

3-59. A/D Converter

3-60. INVERTING AMPLIFIER

3-61. The inverting amplifier consists of input switch Q103, dual FET input amplifier Q101, operational amplifier A101, and associated circuitry. Once every 18 milliseconds, during the zero period for the inverting amplifier (period C of the measurement cycle), switch Q105 is switched on by the autozero drive circuit, which consists of amplifiers Q108 and Q109. The automatic zero circuit consists of transistors Q104 and Q105 and capacitor C116. The drive circuit also supplies a turn-off signal to transistor Q103, thereby removing the input to the inverting amplifier during the zero period.

3-62. POLARITY DETECTOR

3-63. The polarity detector consists of flip flop Q106-Q107 and associated circuitry. The flip flop employs base triggering, which is applied through diode CR110 to the base of Q106. The gate signal (Gate 4), which is applied to the emitters of Q106 and Q107, enables the detector only during period A of the measurement cycle. During the remainder of the measure/store cycle, the plus and

minus gates are turned off and the polarity information is retained by the display circuitry so that a continuous polarity indication is provided.

3-64. A/D AMPLIFIER

3-65. The A/D amplifier consists of dual FET Q115, operational amplifier A102, and associated components. The automatic zero circuit is comprised of transistors Q117 and Q118 and capacitor C115. Switch Q118 is turned on during the zero period of the measurement cycle by a signal from the autozero circuit, consisting of amplifier Q110. Transistor Q110 also controls switches Q113 and Q114, which are turned on during the zero period, and switch Q120, which is turned off during the zero period to disconnect the amplifier output from the ladder. Transistor Q119 and resistor Q180 constitute a clamp, which prevents amplifier A102 from saturating while the output of A102 is above 7 volts.

3-66. ANALOG COMPARATOR

3-67. The analog comparator, consisting of transistors Q116, Q121, Q122, Q123 and associated components, is basically a voltage comparator. Differential amplifier stage Q121 compares the A/D amplifier output with the +7 volt reference, and differential stage Q122, Q123 outputs to the CCO. Transistor Q116 operates as a second comparator, which responds quickly to high voltage levels, thereby allowing maximum time for resolution of the least significant digit.

3-68. SAMPLE AND HOLD

3-69. The sample and hold circuit consists of transistors Q124 through Q127 and capacitors C108 and C109. The sequence of operation for the sample and hold circuit is shown in Figure 3-20.

PERIOD IN CYCLE	SWITCH CONDITION	
	MEASUREMENT CYCLE	STORAGE CYCLE
A	Q125 ON	Q124 Through Q127 OFF
B	Q124, Q127 ON	
C	Q125, Q126 ON	
D	Q124, Q127 ON	
E	Q126 ON	

Figure 3-20. SAMPLE AND HOLD OPERATING SEQUENCE

3-70. LADDER

3-71. The output of the 16-state binary counter is applied to the ladder switches and their drivers, transistors Q133 through Q144. The output of the ladder switches is applied to two ladders. Each ladder comprises a 4-bit, weighted-resistor, digital-to-analog converter. The primary ladder consists of resistors R133 through R139 and produces an output that corresponds to the actual value of the digital input. The secondary ladder, which drives only the display storage circuit, consists of resistors R127 through R132 and produces an output that approximates the actual value of the digital input. The half-digit bias is produced by R131 and R132 in conjunction with the secondary ladder resistors and adds the voltage equivalent of a half-digit to the output of the secondary ladder. This ensures proper display storage readout by compensating for the effects of voltage decay in the storage circuit.

3-72. DISPLAY STORAGE

3-73. The storage circuit consists of FET switches Q128 through Q132, FET switches Q146 and Q147, and capacitors C110 through C114. The output of the secondary ladder is supplied to the appropriate storage capacitor through Q147, which is switched on during display time. The first (most significant) digit is stored in C110, second in C110, second in C111, third in C112, fourth in C113, and the fifth in C114. When the cycle change circuitry switches to storage mode, Q146 is switched on and the analog voltages stored in the capacitors are applied, serially, to the input of Q115.

3-74. Logic and Control

3-75. LOGIC NOTATION

3-76. A description of the logic symbology used in the Model 8350A is given in Figure 3-20. A J-K flip flop that is in the "1" condition or is set "high" has a "high" output from the "Q" terminal. The orientation of the flip flops in the schematics is the same as the flip flop shown in Figure 3-21. This method of notation enables input/output terminals of the flip flops to be identified without the necessity of redundant lettering of each device symbol. In the main, the routing of logic and control signals on the schematics is accomplished without connecting lines, which greatly reduces congestion. The origin of the signals may be determined by locating the device or circuit whose circuit reference symbol bears the same nomenclature, e.g., origin of the Y signal would be flip flop "6Y" of the sixteen state binary counter and, specifically, the Q output of that flip flop.

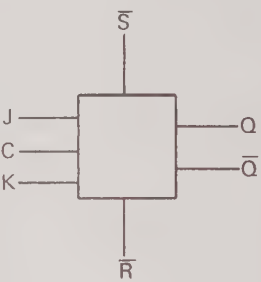
LOGIC SYMBOL	NAME	DESCRIPTION																																	
	J-K Flip Flop	Operation of the J-K flip flop is shown by the following truth tables. Note that "S" and "R" inputs are dominant over "J" and "K" inputs. SYNCHRONOUS INPUTS <table><tr><th colspan="2">tn</th><th>tn + 1</th></tr><tr><th>J</th><th>K</th><th>Q</th></tr><tr><td>0</td><td>0</td><td>Q_n</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>Q_n</td></tr></table> ASYNCHRONOUS INPUTS <table><tr><th>S̄</th><th>R̄</th><th>Q</th></tr><tr><td>0</td><td>0</td><td>Undefined</td></tr><tr><td>0</td><td>1</td><td>1 Set</td></tr><tr><td>1</td><td>0</td><td>0 Reset</td></tr><tr><td>1</td><td>1</td><td>Normal Condition</td></tr></table>	tn		tn + 1	J	K	Q	0	0	Q _n	0	1	0	1	0	1	1	1	Q _n	S̄	R̄	Q	0	0	Undefined	0	1	1 Set	1	0	0 Reset	1	1	Normal Condition
tn		tn + 1																																	
J	K	Q																																	
0	0	Q _n																																	
0	1	0																																	
1	0	1																																	
1	1	Q _n																																	
S̄	R̄	Q																																	
0	0	Undefined																																	
0	1	1 Set																																	
1	0	0 Reset																																	
1	1	Normal Condition																																	

Figure 3-21. EXPLANATION OF LOGIC SYMBOLOGY

3-77. MASTER CLOCK

3-78. The 333 Hz clock signal is produced by transistor Q45. The clock frequency is determined by the RC time constant of resistor R1 and capacitor C1. The output of Q45 is applied to the trigger input of flip flop 3F. The F output of 3F is inverted in Q1 and becomes the H signal. The F, F, and H signals are used by the logic to generate control signals.

3-79. SIX-STATE SHIFT REGISTER

3-80. The shift register consists of J-K flip flops 1A, 1B, 2C, 2D, and 3E. Error-correction gate 4B controls the input to flip flop 1A to ensure proper operation of the shift register. At the beginning of the measurement cycle, the shift register is reset by the M signal, which is differentiated by capacitor C2 and resistor R70 and applied to the reset input of each flip flop. When reset, each flip flop is in the "0" condition, the "J" input of flip flop 1A is high, and the "K" input of flip flop 1A is low. Resetting the shift register initiates the zero period of the A/D amplifier, as shown in the timing diagram of Figure 3-16, and provides a ZERO control signal at pin 8 of gate 4B. The zero period is term-

inated by the H clock pulse, which sets flip flop 1A high and reverses its input. Subsequent clock pulses set the flip flop outputs as shown in Figure 3-22.

3-81. SIXTEEN-STATE BINARY COUNTER

3-82. The sixteen-state binary counter consists of J-K flip flops 6Z, 6Y, 7X, and 7W. The counter is set to zero at the beginning of each period in the measurement cycle by the H clock pulse. During each period of the measurement

PERIOD	SHIFT REGISTER FLIP FLOP OUTPUT STATES				
	1A	1B	2C	2D	3E
ZERO	0	0	0	0	0
A	1	0	0	0	0
B	0	1	0	0	0
C	0	0	1	0	0
D	0	0	0	1	0
E	0	0	0	0	1

Figure 3-22. SHIFT REGISTER OUTPUTS

cycle, the output of the CCO, which is applied to the clock input of flip flop 6Z, is counted. The truth table for the flip flops in the binary counter is shown in Figure 3-23.

CCO PULSE COUNT	SIXTEEN-STATE BINARY COUNTER			
	6Z	6Y	7X	7W
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1
10	0	1	0	1
11	1	1	0	1
12	0	0	1	1

Figure 3-23. SIXTEEN-STATE BINARY COUNTER TRUTH TABLE

3-83. 11'S AND 12'S CATCHER

3-84. The conditional 11's catcher and 12's catcher control the "J" and "K" inputs to flip flop 6Z. The 12's catcher stops the counter unconditionally when it reaches a count of 12. It also enables circuitry which activates the OVERload indicator. The 12's catcher circuit consists of NAND gate 15C and diode CR4. When the count in the binary counter reaches 12, gate 15C will be enabled and the

counter input will be clamped at zero volts dc. Activation of the 12's catcher circuit will also enable switch Q44, and the next pulse from the CCO will turn on transistor Q46, which will activate the OVERload lamp. Q46 will remain on until the beginning of the next measurement cycle, at which time it will be turned off by the M signal, which is applied to its cathode. The 11's catcher consists of NOR gates 8A and 8B and NAND gate 19C. The W, Y, and Z counter outputs are NORed in gate 8A with the output of gate 8B. If the count reaches 11, the W, Y, and Z inputs will be low; if, at the same time gate 8B is enabled, gate 8A will be inhibited, which will enable gate 19C and the counter will be stopped.

3-85. CURRENT CONTROLLED OSCILLATOR

3-86. The CCO consists of multivibrator Q2, Q3. The CCO has no output until it is supplied current by the analog comparator. The pulse repetition rate of the CCO is proportional to the magnitude of the driving current. The greater the current flowing into the base of Q3, the greater the number of pulses produced by the CCO per unit time. The CCO output is applied to the clock input of the 16-state binary counter. The 9's catcher, gate 9C, disables the CCO at a count of nine, if the DVM is digitizing the second through the fifth digits (periods B through E). The purpose of transistor Q4 is to disable the CCO during display time to prevent changing the count during the display period.

3-87. MANUAL RANGE LOGIC

3-88. The manual range logic processes the range commands and overrides the autorange function whenever a range is selected manually. The four range commands and the VDC, MVDC, and 10 MΩ function commands are NORed in gates 12B, 10D, 10B, and 10C. The gates are inhibited if the corresponding range is called, provided that the associated function agrees with the selected range. The operation of the four gates is shown in the truth table of Figure 3-24. The output of these gates is NORed in gates

NOR GATES	VAC AND KΩ				VDC			MVDC		MΩ
	RANGE									
	1	10	100	1000	10	100	1000	100	1000	10
12B	1	0	0	0	0	0	0	0	0	0
10D	0	1	0	0	1	0	0	0	0	0
10B	0	0	1	0	0	1	0	1	0	0
10C	0	0	0	1	0	0	1	0	1	0

Figure 3-24. RANGE GATE TRUTH TABLE

11A, 10A, 12A and 11C to provide set and reset pulses to the range flip flops 18a and 18b. The truth table for the range flip flops is shown below:

RANGE	FLIP FLOP	
	a	b
1	0	0
10	0	1
100	1	0
1000	1	1

3-89. Assume, for example, that the VAC function and the 1 volt range are called. Gate 12B will be inhibited, which will enable gates 11A and 10A. The low output of these gates will be applied to the reset input of flip flops 18a and 18b, thereby setting them to the "0" condition (range 1). In similar manner, each range command enables these gates in such combination as to lock the range flip flops in the desired condition. Calling the MVDC function enables gates 12B and 12C so that only 100 and 1000 ranges may be called. Likewise, calling the 10 M Ω function enables gates 12B, 10B, and 10D so that only the 10 range is enabled; at the same time, calling the 10 M Ω function enables gate 11A and 12A, which sets flip flop 18a to the "0" condition and flip flop 18b to the "1" condition. In this way, the 10 range is automatically called whenever the 10 M Ω function is called.

3-90. NOR gate 8B is the enabling gate for the conditional 11's catcher. It will be enabled if the 1, 10, or 100 ranges are called or if the 10 M Ω function is called. If the 1000 range is called, NOR gate 16B will be inhibited, which will also enable gate 8B. NOR gates 11B and 13A constitute an interlock to prevent calling the 1 range in VDC function. Calling VDC function and range 1 enables gate 12A, which sets flip flop 18b, thereby locking the DVM out of range 1.

3-91. AUTORANGE LOGIC

3-92. The range flip flops 18a and 18b are controlled by uprange and downrange gates together with a ranging pulse circuit. Up-signal (UP) detection is accomplished by NAND gate 15C and down-signal (DN) detection is accomplished by NAND gate 4A. When the binary counter reaches a count of 12, gate 15C is enabled and will produce a low at pin 11 of gate 13C. At the same time, gate 13D will be enabled by a high from the downrange detector, gate 4A. The other input to gates 13D and 13C is supplied by flip flop 18b. If flip flop 18b is in the "0" condition, gates 13D and 13C will produce a low at both "J" and "K"

inputs of flip flop 18a. Thus when the ranging pulse is applied to flip flops 18a and 18b, flip flop 18a will remain in its previous state and flip flop 18b will toggle. If flip flop 18b is in the "1" condition, gates 13D and 13C will produce a low and a high, respectively, at the "J" and "K" inputs of flip flop 18a. The ranging pulse will then cause both flip flops 18a and 18b to toggle.

3-93. The ranging pulse is developed by gates 19A, 19B, and 16A in conjunction with the 230 milliseconds delay circuitry. The UP and DN signals are Nanded in gate 19A to produce a high output from 19A if either an UP or DN signal is generated or a low output if either is generated. Gate 19A and diode CR10 constitute a two-input AND gate, which provides an UP or DN command to gate 19B only during the A period of the measurement cycle. Gate 19B is enabled at the beginning of the second half of the A period, when the F signal goes high, if there has been an up or down range decision. The output of gate 19B is differentiated and applied as a negative pulse to NOR gate 16A. The positive pulse developed by gate 16A is applied to the clock inputs of the range flip flops and causes them to uprange or downrange, depending on the state of gates 13D and 13C.

3-94. The delay circuitry places the DMM in storage mode during the ranging operation to allow the signal conditioners to stabilize before proceeding with a measurement. This action is initiated by the ranging pulse. It is applied to the flip flop (gate 5B and 5C) of the cycle change circuitry, which causes the cycle change circuitry to change to storage mode.

3-95. The purpose of gates 15A, 15B, 15D, and 13B and diodes CR13 and CR14 is to set the lowest range for the selection function, thereby setting the operating range of the autorange circuitry. Diode CR13 inhibits the down detection gate, 4A, when the 100 range is manually selected, and diode CR14 inhibits gate 4A when the 10 or 100 range is selected. On the 10 volt range in VDC mode, gate 13A will be enabled, gate 15A will be inhibited, and gate 15D will be enabled, which will inhibit the down detection gate, 4A. On the 100 range in MVDC mode, gate 13B will be enabled, gates 15A and 15B will be inhibited, and gate 15D will be enabled, which will also inhibit the down detection gate.

3-96. CYCLE CHANGE CIRCUITRY

3-97. The cycle change circuitry consists of two flip flops, an inverter, and a reset gate. The input flip flop consists of NOR gates 5C and 5B, and the output flip flop consists of gates 16C and 16D. Following application of the H

pulse, the information present in the input flip flop is inverted in gates 9A and 5A and passed on to the output flip flop. The $\overline{\text{ZERO}}$ signal, which is applied to one input of gate 5A, prevents the circuitry from being cycled until it has completed the current cycle. In measurement cycle, gates 5C and 16D are enabled; and in storage cycle, gates 5B and 16C are enabled. The reset gate, 9C, produces a reset signal at the end of the E period of the storage cycle, which switches the DVM to the measurement cycle. The cycle change flow chart is shown in Figure 3-25.

3-98. INTERNAL SAMPLE OSCILLATOR

3-99. The internal sample oscillator consists of transistors Q27, Q42, Q43 and associated components. Transistors Q27 and Q42 constitute a Schmitt trigger. The stage is triggered by the charge on capacitor C9, as it charges through resistor R48. After changing state, the positive potential at the collector of Q27 turns on transistor Q43 and quickly discharges capacitor C9 to restore the initial state. The output pulse width is determined by the discharge time of C9 and the hysteresis characteristics of the Schmitt circuit. The

pulse repetition rate is determined by the RC time constant of R48 and C9.

3-100. ANALOG CYCLE CONTROLS

3-101. The analog cycle control circuitry produces the gate and control signals, which are used to control the timing of events in the analog portion of the DVM, principally the A/D converter. These signals, together with other control signals, are shown in the timing diagram of Figure 3-16. The M and $\overline{\text{H}}$ signals are NANDed in gate 14D and the output of the gate is applied to inverter Q11, which is enabled by quantity $\overline{\text{C}} \cdot \overline{\text{E}}$ from gate 14C. The resulting signal, gate 11, represents the quantity $\overline{\text{MH}}$ ($\text{C} + \text{E}$). The "store input" control signal is equivalent to the $\overline{\text{F}}$ signal and is produced by transistor Q12. The quantity $\overline{\text{MH}}$ from gate 14D is applied to inverter Q13, which is enabled by quantity $\overline{\text{A}} \cdot \overline{\text{C}}$ from gate 14B. The resulting signal, gate 2, represents the quantity $\overline{\text{MH}}$ ($\text{A} + \text{C}$). The quantity $\overline{\text{MH}}$, from gate 14D, is also applied to inverter Q14, which is enabled by quantity $\text{B} \cdot \text{D}$ from gate 14A. The resulting signal, gates 1 and 22, represents the quantity $\overline{\text{MH}}$ ($\text{B} + \text{D}$).

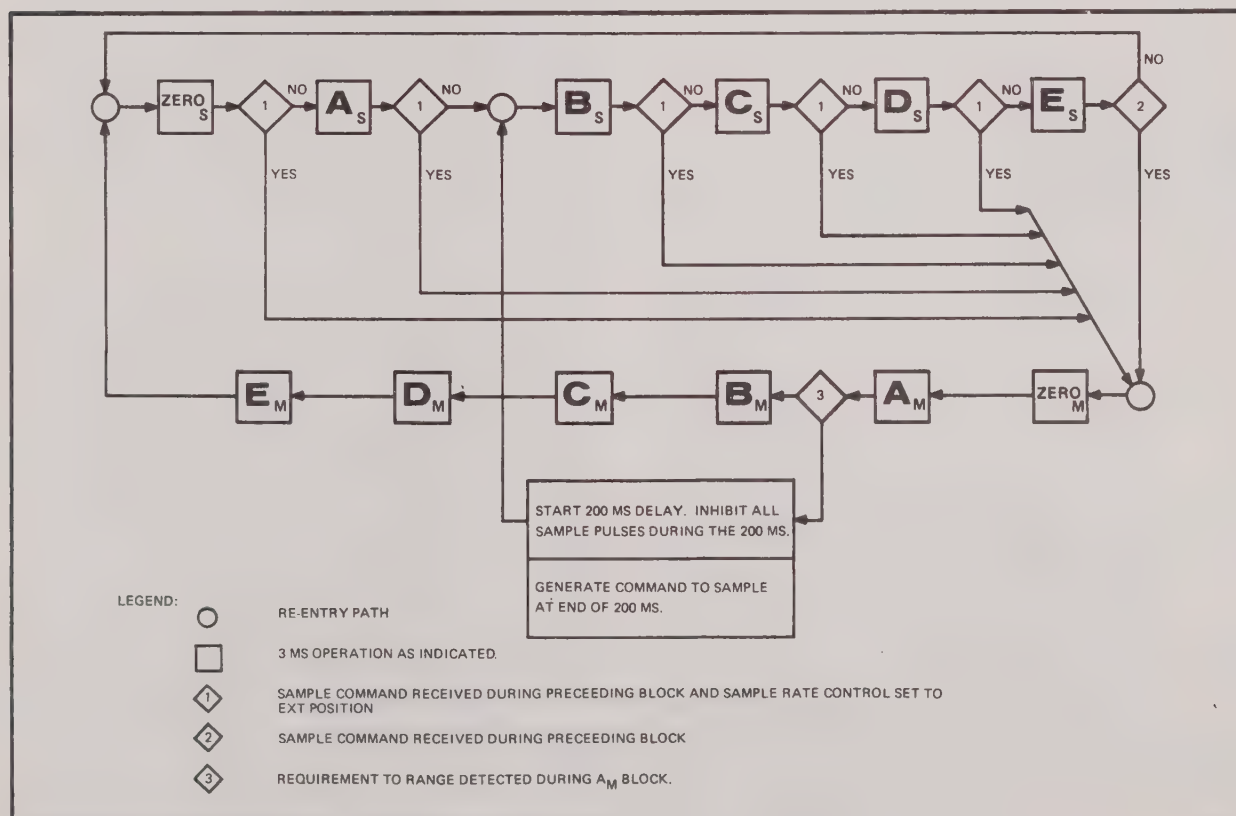


Figure 3-25. CYCLE CHANGE FLOW CHART

The "store output" control signal is equivalent to the M signal and is produced by transistor Q15. The gate 4 signal is produced by transistor Q16 and is equivalent to M·A.

3-102. DISPLAY CIRCUITRY

3-103. The display circuitry controls the function/status indicators and the decimal indicators associated with the readout tubes. The AC, MV, K Ω , and M Ω indicators are controlled by the respective function control lines. They are illuminated when +5 volts dc is applied to the control line; however, the control lines are interlocked in the associated assembly so that the indicator will not light unless the assembly is installed in the instrument. The OVERload indicator is operated by transistor Q44 in conjunction with the 12's catcher, as described in paragraph 3-84.

3-104. The DC+ and DC- indicators are controlled by a flip flop consisting of transistors Q17 and Q18, FET switches Q19 and Q20, and associated components. Diodes CR6 and CR7 comprise an OR gate, which is enabled if either VDC or MVDC functions are called, thereby supplying +5 volts dc to one terminal of each polarity indicator. At the beginning of the measure cycle, Q17 is triggered on by the $\bar{M}$ signal through diode CR11, which turns off Q17, turns on Q18, and lights the DC+ indicator. If the DVM is in VDC mode and a positive instrument input voltage is detected, the polarity detector (located in the A/D converter) will turn on switch Q19, thereby connecting the MVDC control line to the base of Q17. Since the MVDC control line is low, Q17 will remain off and the DC+ indicator will remain on. If a negative instrument input voltage is detected, switch Q20 will be turned on which, will turn on Q17 and light the DC- indicator. If the DVM is in MVDC mode and a positive instrument input is detected, Q20 will be turned on and, since the VDC line is low, Q17 will remain off and the DC+ indicator will remain lighted. For a negative input, Q19 and Q17 will be on, thus lighting the DC- indicator. The decimal point indicators are controlled by transistor switches Q21 through Q24, which are operated by the range flip flops 18a and 18b.

3-105. ANODE STROBING CONTROL

3-106. Switches Q31 through Q35 are turned on sequentially by the shift register signals, A through E, beginning with signal A. The F signal ensures that the transistors are

turned on only during the second half (display portion) of each period. The output of these switches controls switches Q36 through Q40, which apply +190 volts dc to the anode of each readout tube.

3-107. MISCELLANEOUS CIRCUITRY

3-108. The overrange indicator V1, is operated by transistor Q41, which is connected to the "1" digit of V1. Q41 is controlled by the W and $\bar{Y}$ outputs of the 16-state binary counter and is turned on when the counter reaches a count of 10. The decoder/driver is a monolithic Binary-Coded-Decimal to Decimal decoder, which accepts the 4-bit BCD output of the 16-state binary counter, decodes each digital word, and selects one of ten decimal output drivers. The ten outputs are applied to the readout cathodes. Transistors Q29 and Q30 buffer the range flip flop outputs for use in the buffer, where they control the range relays.

3-109. Power Supply

3-110. The +18 and -18 volt regulators obtain filtered dc voltage from two full-wave rectifiers consisting of diodes CR205 through CR208 and filter capacitors C202 and C206. The +18 volt regulator consists of differential amplifier Q209, Q210, driver Q204 and series pass transistor Q203. The voltage reference for the +18 volt regulator is zener diode CR219. The -18 volt regulator consists of differential amplifier Q211, Q212, driver Q213, and series pass transistor Q214. The -18 volt regulator is referenced to +18 volt.

3-111. Regulated +18 volts is supplied to the +7 volt regulator, which constitutes the master voltage reference for the instrument. It consists of reference amplifier A201, Q207, Q208, FET switch Q218, driver Q206, and series pass transistor Q205. Switch Q218 is turned off during external reference operation to disable the +7 volt reference. The sample string, consisting of resistors R213, R222, and R235, is connected to the ladder switches in the A/D converter so that voltage variations in the ladder will be held to a minimum.

3-112. The +190 volt regulator is operated from a full-wave bridge rectifier and filter consisting of diodes CR201 through CR204 and capacitor C201. The reference for the +190 volt regulator is regulated +18 volts. Voltage variations are amplified in Q202 and applied to series pass transistor Q201.

Section 4

Maintenance

4-1. INTRODUCTION

4-2. This section contains information and instructions concerning preventive and corrective maintenance for the Model 8350A Digital Multimeter. Preventive maintenance consists primarily of cleaning the instrument and should be performed as often as operating conditions require. Corrective maintenance consists of troubleshooting, calibration, and performance test procedures, which are designed to aid in maintaining instrument operation within specifications. Section III of the instruction manual is an important supplement to the troubleshooting section, since a knowledge of instrument theory is indispensable in troubleshooting.

4-3. A calibration interval of 90 days is recommended to ensure instrument operation within the 90-day specifications stated in Section I of the manual. A calibration check every 24 hours is necessary for operation within the 24-hour specifications. The performance of the instrument should be verified in accordance with the performance test paragraph 4-19 before calibration is attempted. An instrument that does not meet all of the requirements of the performance test will require troubleshooting and/or calibration.

4-4. SERVICE INFORMATION

4-5. Each instrument manufactured by the John Fluke Mfg. Co., Inc. is warranted for a period of one year upon delivery to the original purchaser. Complete warranty information is contained in the Warranty page located at the rear of the manual. Factory authorized calibration and repair service for all Fluke instruments is available at

various world-wide locations. A complete list of factory authorized service centers is located at the rear of the manual. If requested, an estimate will be provided to the customer before any repair work is begun on instruments which are beyond the warranty period.

4-6. TEST EQUIPMENT

4-7. The equipment recommended for performance testing, troubleshooting, and calibration of the Model 8350A is listed in Figure 4-1. If the recommended equipment is not available, other equipment which meets the required specifications may be used.

EQUIPMENT NOMENCLATURE	RECOMMENDED EQUIPMENT
Oscilloscope Oscilloscope Plug-in Oscilloscope Probes	Tektronix Model 547 Tektronix Model 1A1 Tektronix Model P6010
DC Voltage Source	Fluke Model 343A DC Voltage Calibrator
AC Voltage Source	Fluke Model 5200A 5205A Amplifier
Differential Voltmeter	Fluke Model 885A
Multimeter	Fluke Model 8100B
Standard Resistors 1K 10K 100K 1000K 10 MΩ	General Radio Type 1440, Standard Resistors

Figure 4-1. TEST AND CALIBRATION EQUIPMENT

4-8. GENERAL MAINTENANCE

4-9. Access/Disassembly

4-10. The following procedure may be used to gain access to various portions of the instrument.

- a. Remove the top and bottom dust covers to gain access to calibration adjustments and test points of the instrument. See Figure 4-2.
- b. Remove the buffer board to gain access to components on the buffer assembly as well as components on the Logic and A/D assembly.
- c. Remove the bottom inner guard cover to gain access to the land-pattern side of the Logic and A/D assembly.

4-11. Fuse Replacement

4-12. The line fuse is located in a fuseholder mounted on the rear panel of the instrument. The MV/Ohms Converter fuse protects the instrument in the event ac or dc voltages are applied to the instrument during ohms operations. Correct values for fuses are as follows:

REFERENCE DESIGNATION	FUNCTION	RATING
F1	Line fuse	AGC ½ Amp
F1	Ohmmeter fuse	1/20 Amp Microfuse

4-13. 115/230 Volt Conversion

4-14. The Model 8350A may be operated from either 115 or 230 volt ac power, depending upon the connection of the power transformer primary winding. Convert the instrument from one type of power line operation to the other by the following procedure:

- a. Disconnect the instrument from the line.
- b. Place the 115/230 slide switch, located at the rear of the instrument, in the position which corresponds to the desired operating voltage.

4-15. Lamp and Tube Replacement

4-16. The readout tubes (V1 through V6) and the function/status indicator lamps are mounted behind the

left portion of the front panel. These components are replaced without special tools using the following procedure:

- a. Remove the top and bottom dust covers and inner guard chassis covers.
- b. If the function/status indicator lamps are to be replaced, perform steps (c) and (d). Perform steps (f) through (g) to replace the readout tubes.
- c. Remove the function/status indicator assembly mounting screws. Access to these mounting screws is from the bottom of the instrument.
- d. Remove the function/status assembly from the top of the instrument. After removal of the plexiglass cover on the assembly, the defective lamp may be replaced by carefully unsoldering the old lamp, clearing the holes of solder, and soldering in the new lamp.

CAUTION!

Use a desoldering tool and exercise extreme caution to avoid lifting land patterns.

- e. To replace the overrange indicator tube or the two adjacent readout tubes, unsolder the base mounting pins and remove the tube from the top of the instrument.
- f. Replacement of the three lower order readout tubes is accomplished in the same manner after first removing the buffer board.

4-17. Cleaning

4-18. The instrument should be cleaned periodically to remove dust, grease, and other contamination. Cleaning should not be necessary too often, however, since the instrument is completely enclosed and contains no fans or vents. Care has been taken in design to prevent leakage, through the use of high quality insulation materials and through special attention to component locations. The following procedure should be adhered to when cleaning the instrument.

- a. Remove loose contamination with low-pressure clean, dry air. Pay particular attention to the front panel binding posts and binding post wiring.

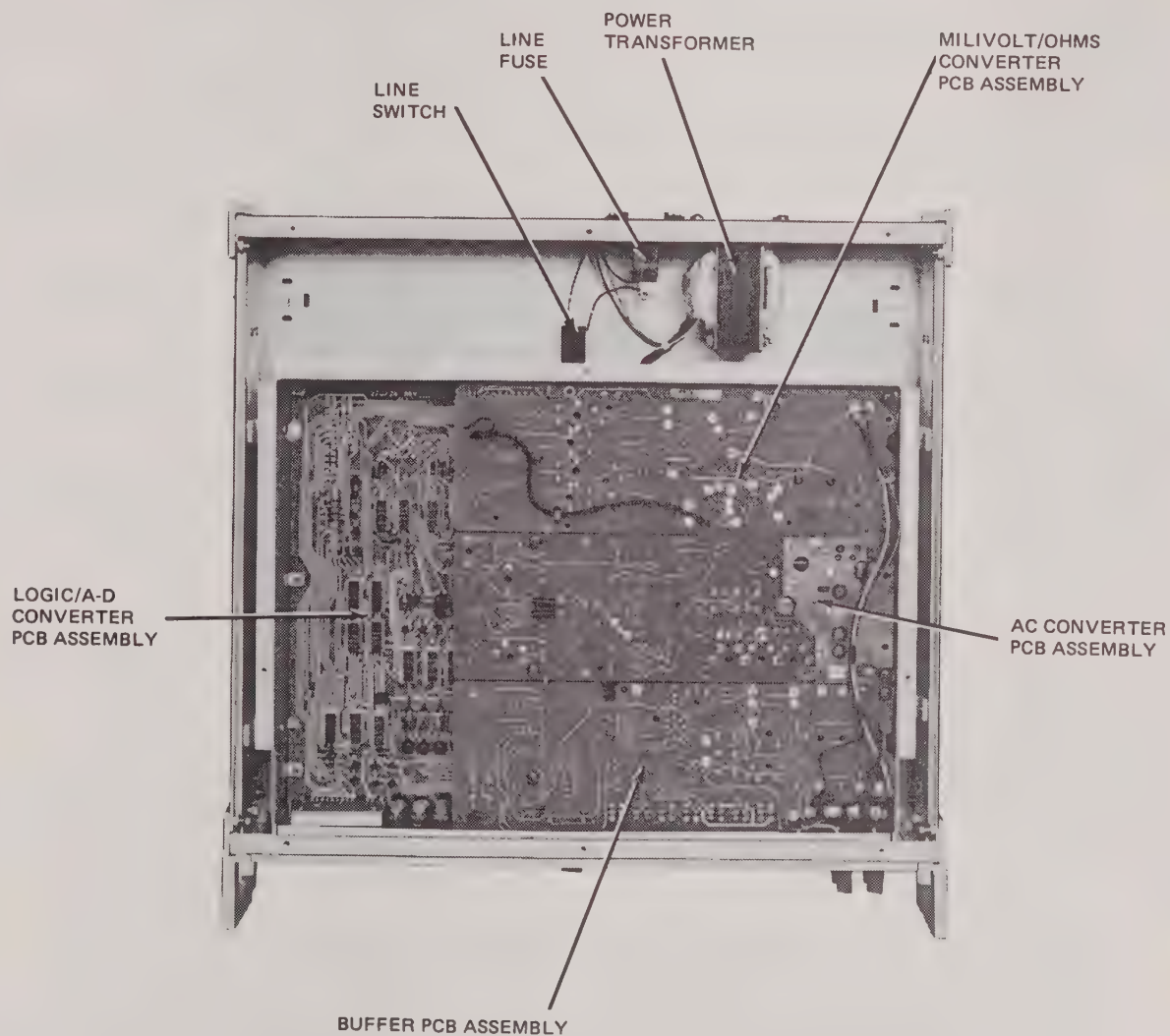


Figure 4-2. ASSEMBLY LOCATIONS

- b. Clean the front panel and exterior surfaces with anhydrous ethyl alcohol or a soft cloth dampened in a mild solution of detergent and water.

CAUTION!

Do not use aromatic hydrocarbons or chlorinated solvents on the front panel, because they will react with the Lexan binding posts.

- c. Clean printed circuit boards by first spraying with Freon TF Degreaser (MS180 Miller Stephensen Chemical Co., Inc.) followed by application of low pressure, clean, dry air.

4-19. PERFORMANCE TEST

4-20. The performance test in this section compares instrument performance to the accuracy specification in Section I of the manual to determine if the instrument is in calibration. Known voltages and resistances are applied to the instrument input terminals on each of the ranges and proper operation of the manual range and autorange circuitry is verified. The performance tests should be conducted before any instrument maintenance or calibration is attempted. The tests are also suited to receiving inspection of new instruments. The tests should be conducted under the following conditions: ambient temperature 25°C ±5°C, relative humidity less than 70%. An instrument that fails the tests will require corrective maintenance or calibration. In case of difficulty, analysis of the test results, with reference to the troubleshooting section, should help to locate the trouble.

NOTE!

Permissible tolerances are derived from the 90-day instrument specifications contained in Section I of the manual.

4-21. DC Voltage Test

4-22. In the following procedure, dc voltages are applied to the instrument at 10% and 100% of full scale on the 10, 100, and 1000 volt ranges.

- a. Connect the Model 8350A to the ac line and set the controls as follows:

POWER	ON
FUNCTION	VDC
RANGE	Manually selected, as required

- b. With no input to the instrument, depress the AUTO RANGE switch. The readout should be 00.000.
- c. Select RANGE as required, then apply each of the input voltages shown in Figure 4-3, in turn, to the INPUT terminals of the Model 8350A. The readout limits should be as indicated.

INPUT (VOLTS DC)	MODEL 8350A	
	RANGE	READOUT LIMITS
+1	10	+0.9996 to +1.0004
+10	10	+9.9987 to +10.0013
+10	100	+9.996 to +10.004
+100	100	+99.987 to +100.013
+100	1000	+99.96 to +100.04
+1000	1000	+999.87 to +1000.13

Figure 4-3. DC VOLTAGE TEST REQUIREMENTS

- d. Repeat step (c) with negative input voltages. The readout limits should be the same as for positive inputs, except that the polarity indication be negative (DC-).
- e. Depress the AUTO RANGE switch, then apply 1000 volts dc to the INPUT terminals. The instrument should range automatically and the readout should be +999.87 to +1000.13.

4-23. AC Voltage Test

4-24. In the following procedure, 20 kHz voltages are applied to the instrument at 100% of full scale on the 1, 10, and 100 volt ranges and at 0.1% and 100% of full scale on the 1000 volt range.

- a. Set the Model 8350A controls as follows:

FUNCTION	VAC
RANGE	Manually selected, as required

- b. Apply each of the 20 kHz test signals shown in Figure 4-4 to the INPUT terminals of the Model 8350A. The readout limits should be as indicated.

INPUT (VAC)	MODEL 8350A	
	RANGE	READOUT LIMITS
1	1	.99870 to 1.00130
10	10	9.9870 to 10.0130
100	100	99.870 to 100.130
1	1000	000.70 to 001.30
1000	1000	998.70 to 1001.30

Figure 4-4. AC VOLTAGE TEST REQUIREMENTS

4-25. DC Millivolts Test

4-26. In the following procedure, dc voltages are applied to the instrument at 10% and 100% of full scale on the 100 and 1000 millivolt ranges.

- a. Set the Model 8350A controls as follows:

FUNCTION	MVDC
RANGE	Manually selected, as required

- b. With no input to the instrument, depress the AUTO RANGE switch. The readout should be 00.000.
- c. Select the RANGE as required, then apply each of the input voltages shown in Figure 4-5 in turn, to the INPUT terminals of the Model 8350A. The readout limits should be as indicated.
- d. Repeat step (c) with negative input voltages. The readout limits should be the same as for positive inputs, except that the polarity indication should be negative (MV, DC-).

INPUT (MILLIVOLTS) DC	MODEL 8350A	
	RANGE	READOUT LIMITS
+10	100	+09.989 to +10.011
+100	100	+99.980 to +100.020
+100	1000	+099.96 to +0100.04
+1000	1000	+999.80 to +1000.20

Figure 4-5. MILLIVOLTS TEST REQUIREMENTS

- e. Depress the AUTO RANGE switch, then apply 1000 millivolts dc to the INPUT terminals. The instrument should range automatically and the readout should be between +999.80 and +1000.20.

4-27. Ohms Test

4-28. The ohms function is checked at full scale on each ohms range of the multimeter. Connect each of the standard resistors shown in Figure 4-6 in turn to the INPUT terminals of the Model 8350A. Use short, low-resistance connecting leads. Set the controls as shown in the figure. The readout limits should be as indicated.

STANDARD RESISTANCE	MODEL 8350A		
	FUNCTION	RANGE	READOUT LIMITS
1K	K Ω	1	.99987 to 1.0013
10K	K Ω	10	9.9987 to 10.0013
100K	K Ω	1000	999.87 to 1000.13
10 M Ω	10 M Ω		9.9947 to 10.0053

Figure 4-6. OHMS TEST REQUIREMENTS

4-29. TROUBLESHOOTING

4-30. This section contains information selected to assist in troubleshooting the Model 8350A. Before attempting to troubleshoot the instrument, however, it should be verified that the trouble is actually in the instrument and is not caused by faulty external equipment or improper control settings. For this reason, the performance test (paragraph 4-19) is suggested as a first step in troubleshooting. The performance test may also help to localize the trouble to a particular section of the instrument. If the performance test fails to localize the trouble, the following information may be helpful. Location of principal circuitry areas in the Model 8350A is shown in Figure 4-7. A detailed drawing of the interconnect assembly is shown in Figure 4-8, together with a table of pin assignments. Note that the terminals on the actual assembly are not numbered; they are included on the drawing of Figure 4-8 for reference purposes. Figure 4-23 gives test point and adjustment locations and integrated circuit orientation.

4-31. Power Supply

4-32. In this test, each of the power supply output voltages is checked, using the Fluke Model 885A Differential Voltmeter.

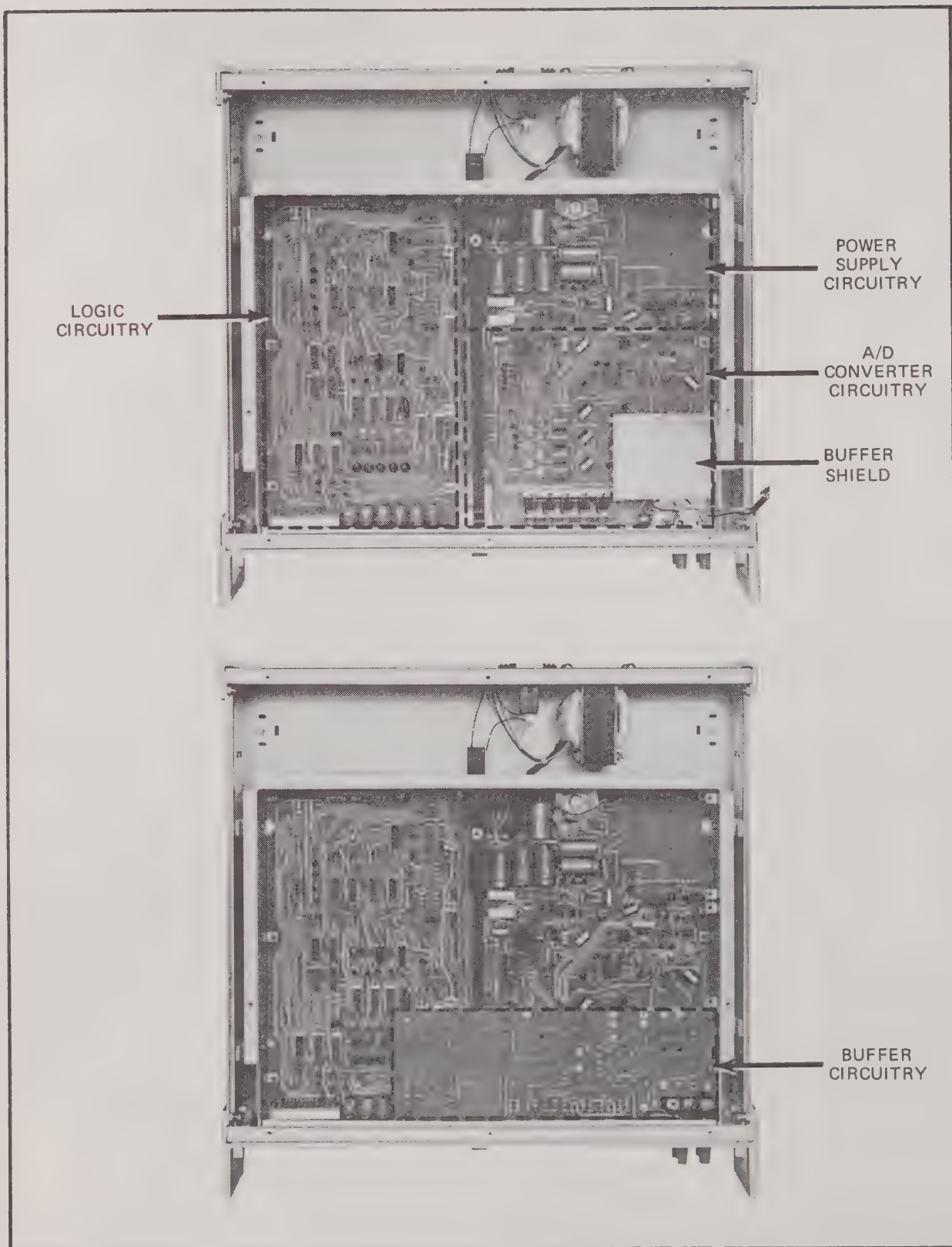
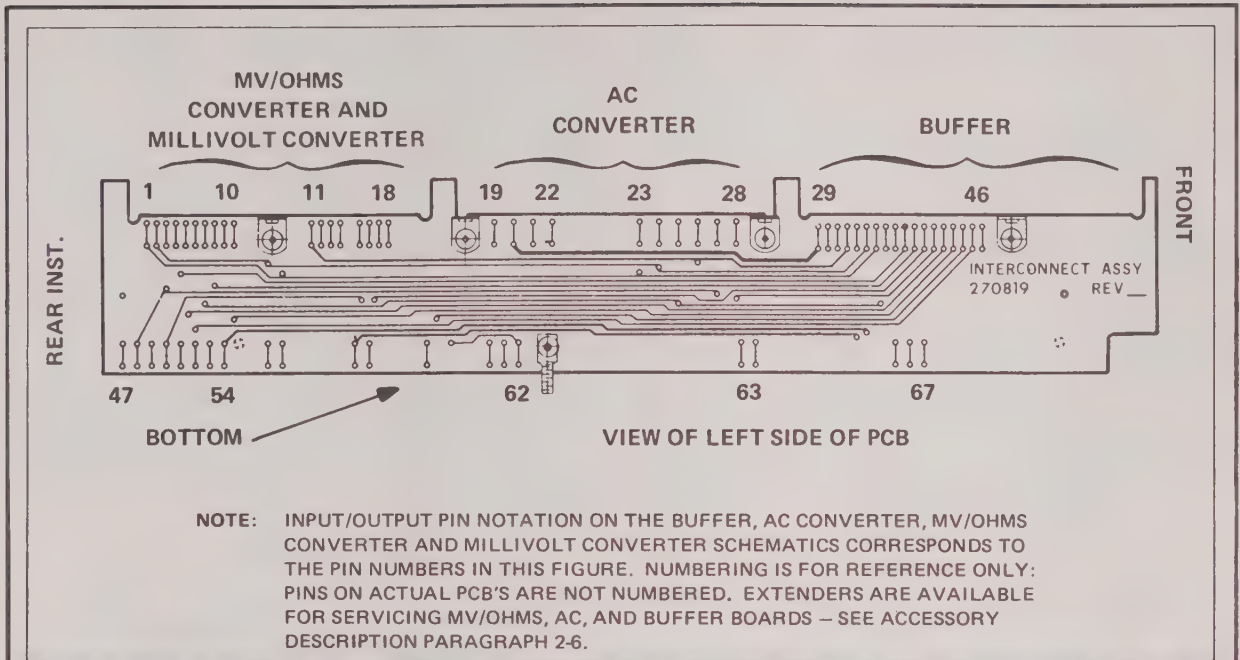


Figure 4-7. MODEL 8350A PRINCIPAL CIRCUITRY AREAS



PIN	DESIGNATION	PIN	DESIGNATION
1	RANGE b	35	RANGE b
2	RANGE a		
4 }	K Ω CONTROL	39	VDC CONTROL
5 }		40	MV CONTROL
6	K8 CONTROL	41	AC CONTROL
7	MV/ Ω OUTPUT TO A/D	42	K Ω CONTROL
		43	M Ω CONTROL
9 }	M Ω CONTROL	44	AC ZERO
10 }		45	K8 CONTROL
11	LOGIC COMMON	46	BUFFER OUTPUT TO A/D
12	7V REF	47	K Ω CONTROL
13 }	MV CONTROL	48	AC CONTROL
14 }		49	EXT REF CONTROL
15	SIGNAL COMMON	50	MV CONTROL
16	+18V		
17	MV ZERO	52	DC CONTROL
18	-18V	53	M Ω CONTROL
19	AC ZERO		
20	SIGNAL COMMON	55	RANGE a
21	+18V	56	RANGE b
22	-18V	57	+5V
23	RANGE b	58	LOGIC COMMON
24	RANGE a	59	SIGNAL COMMON
25	AC OUTPUT TO A/D	60	+18V
26	LOGIC COMMON	61	-18V
27 }	AC CONTROL	62	+7V REF
28 }		63	INPUT TO A/D
29	SIGNAL COMMON	64	SIGNAL COMMON
30	+18	65	MV ZERO
31	-18	66	EXT REF CONTROL
32	LOGIC COMMON		
33	+5V		
34	RANGE a		

Figure 4-8. INTERCONNECT ASSEMBLY

- a. Turn on the instrument. FUNCTION and RANGE switches may be in any position.
- b. Connect the voltmeter common to test point 109 (TP 109) and measure voltages shown in the Figure 4-9. The voltages should be as indicated.

VOLTAGE TEST POINT	NOMINAL	DC VOLTS LIMITS	ADJUSTMENT
TP 204	+18	+17.98 to +18.02	R234
TP 203	-18	-17.5 to -18.5	None
TP 202	+190	+185 to +195	None
TP 205	+7	6.99998 to 7.00002	R22

Figure 4-9. POWER SUPPLY VOLTAGE REQUIREMENTS

4-33. DVM Logic

4-34. The Model 8350A logic may be divided into a number of somewhat independent sections for purposes of trouble analysis. These sections are as follows:

- a. Master clock, F, H
- b. Shift register
- c. VCO and counter, including conditional stops
- d. Display
 1. Incandescent circuits: overload and polarity
 2. Readout tubes: anodes, cathodes, and decimals
- e. A/D controls
 1. w, x, y, z, and zero.
 2. Gates 1, 2, 11, 22, and 4.
 3. Storage in and out.
- f. Automatic ranging
- g. Manual ranging
- h. Sample oscillator
- i. Cycle control circuitry
- j. Analog storage controls

Refer to the figure (Figures 4-10 through 4-15) which pertains to the suspected section as indicated by the symptoms. Waveforms and logic functions are given for every significant point. Figures 4-16 and 4-17 are troubleshooting charts, which are intended to aid in isolating troubles in the analog and display circuitry. Do not overlook the possibility of shorts, which can cause certain IC's to appear inoperative, or improperly installed IC's having pins bent under and/or installed end-for-end (reversed). Also, under conditions of malfunction, spikes that are too fast to be seen on the recommended oscilloscope (Tektronix Model 547) may occasionally be present. The logic sections depend upon each other to some extent for proper operation; e.g., often a non-functioning autorange circuit will be caused by a problem in a manual ranging circuit.

NOTE!

Integared circuit (IC) designations refer to like numbered devices appearing on the schematic. They may be located in the instrument by referring to the parts list and accompanying component callouts.

4-35. AC Converter

4-36. This section contains information selected to aid in troubleshooting the AC converter. Before attempting to troubleshoot the unit, however, it should be verified that the trouble is actually in the converter and is not caused by faulty external equipments or improper control settings. For this reason, the performance test (paragraph 4-19) is suggested as a first step in troubleshooting.

4-37. SUPPLY VOLTAGE CHECK

4-38. In this test, each of the supply voltages for the AC converter is checked at the pin connectors. This test verifies only presence of voltages; a detailed check of power supply voltages is given in paragraph 4-31 of the manual.

- a. Connect the oscilloscope common to TP2 of the converter. Use the internal dc oscilloscope trigger. Set the scope controls for dc voltage measurement, and check the following voltages:

CONNECTOR PIN NO.	REQUIRED VOLTAGE
22	-18 volts
21	+18 volts
19	-18V to +18V
	(rotate front panel AC Zero control)

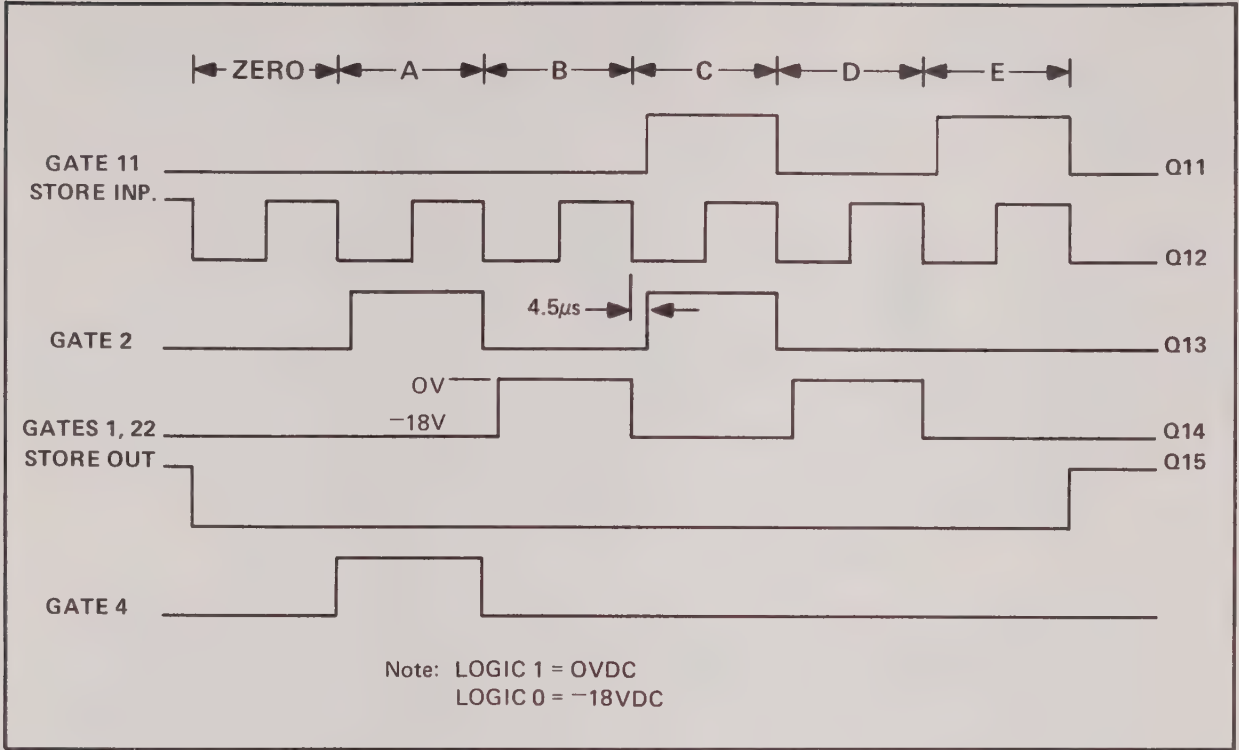


Figure 4-10. A/D CONVERTER CONTROLS

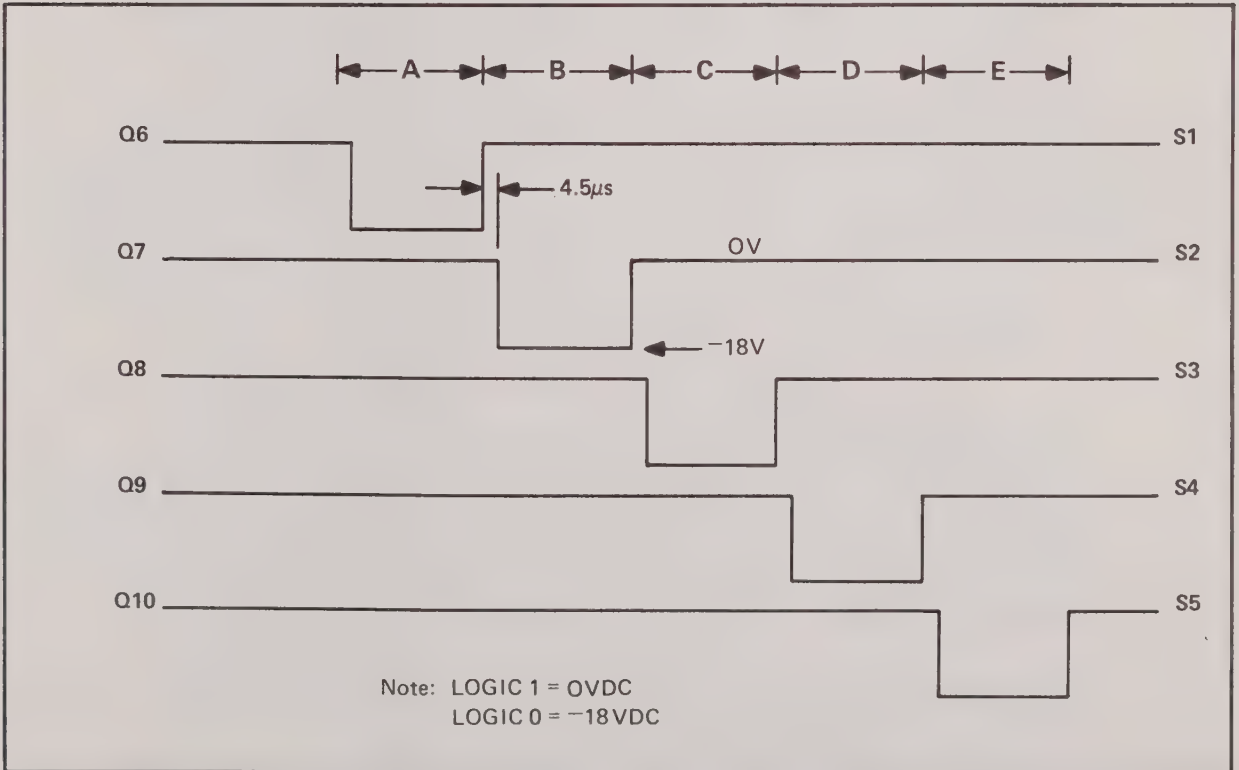


Figure 4-11. ANALOG STORAGE CONTROL

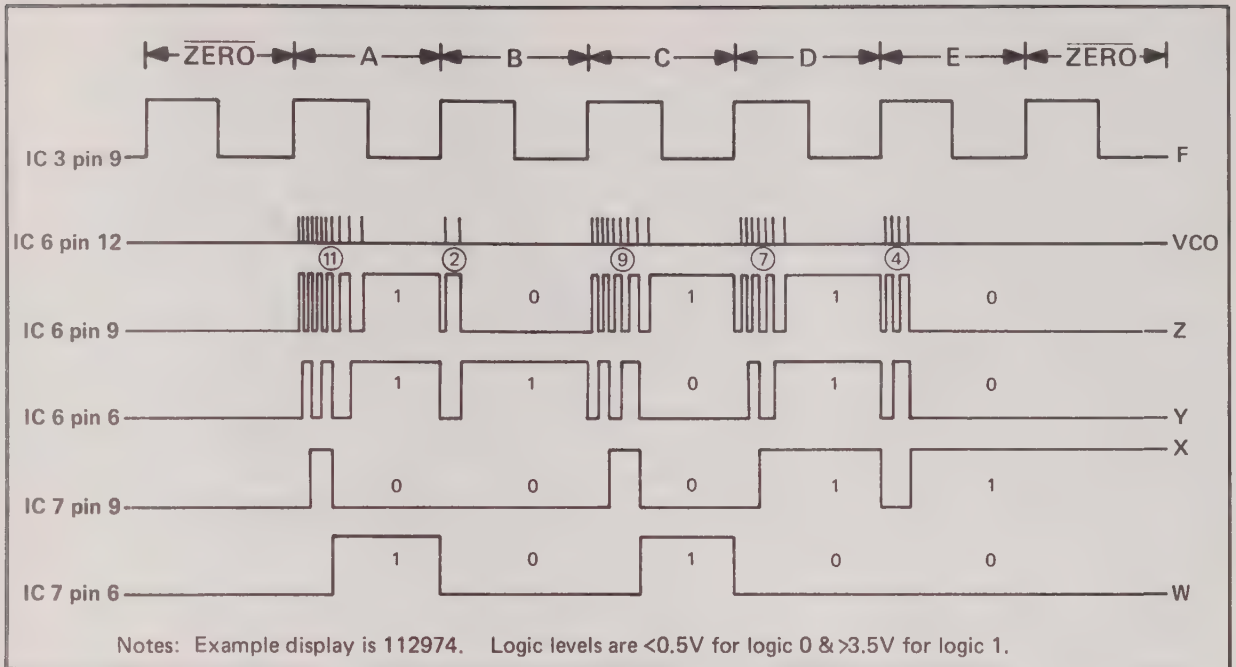


Figure 4-12. COUNTER OPERATION

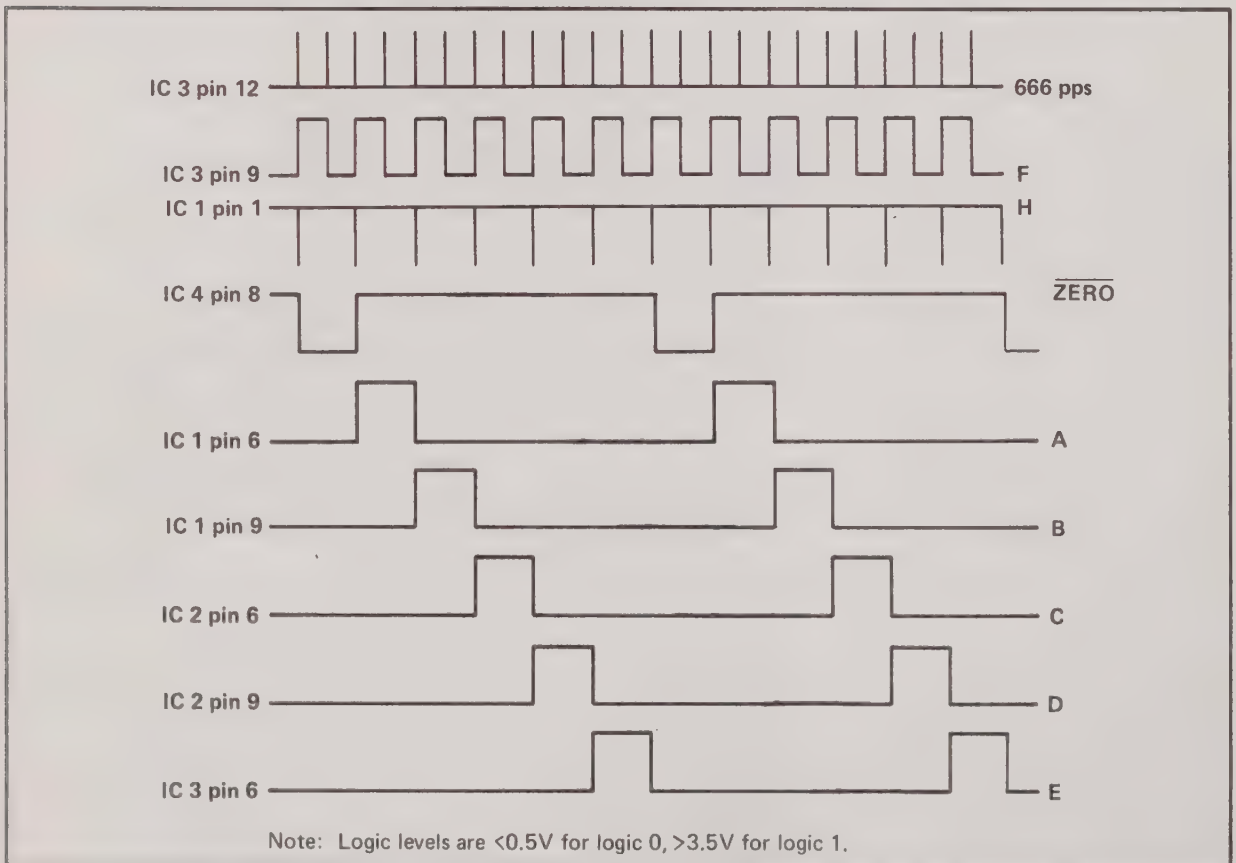


Figure 4-13. SHIFT REGISTER OPERATION

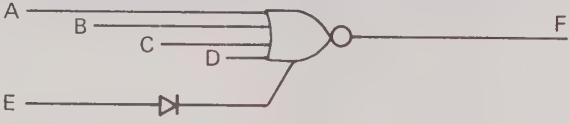
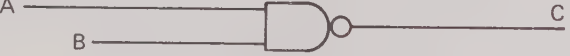
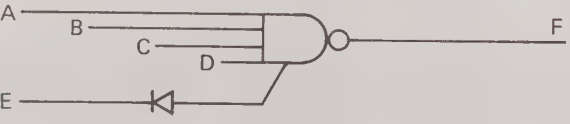
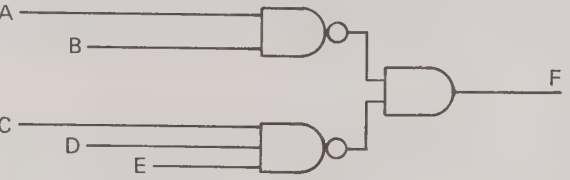
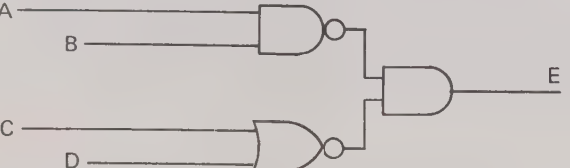
DEVICE	LOGICAL TRANSFER FUNCTION
	$A + B = \overline{C}$
	$A + B + C = \overline{D}$
	$A + B + C + D + E = \overline{F}$
	$A = \overline{B}$
	$A B = \overline{C}$
	$A B C = \overline{D}$
	$A B C D E = \overline{F}$
	$(A + B) (C + D + E) = \overline{F}$
	$(A + B) (\overline{C D}) = \overline{E}$

Figure 4-14. LOGICAL TRANSFER FUNCTIONS FOR DEVICES USED IN THE MODEL 8350A.

DEVICE	PIN NO.	LOGIC FUNCTION
IC12	14	$1 \overline{VDC} \overline{M\Omega} \overline{MV}$
IC10	14	$10 \overline{MV}$
IC10	3	$100 \overline{M\Omega}$
IC10	13	$1000 \overline{M\Omega}$
IC11	2	$1 \overline{VDC} \overline{MV} + M\Omega + 10 \overline{MV}$
IC11	14	$100 \overline{M\Omega} + MV + 1000 \overline{M\Omega}$
IC12	2	$10 \overline{MV} + M\Omega + 1000 \overline{DCab}$
IC10	2	$100 \overline{M\Omega} + 1 \overline{VDC} \overline{M\Omega} \overline{MV}$
IC4	6	$\overline{ab} + \overline{aVDC} + \overline{bMV} + 100 + 1000 + 10 \overline{MV}$ $+ M\Omega + \overline{WX\overline{YZ}}$
IC15	11	$\overline{ab} + \overline{aVDC} + \overline{bMV}$
IC15	6	$\overline{a} + MV$
IC15	3	$\overline{b} + VDC$
IC15	8	$\overline{WX}$
IC13	13	WXb
IC13	14	$\overline{ab} \overline{aVDC} \overline{bMV} \overline{100} \overline{1000} \overline{10MV} \overline{M\Omega} \overline{WXYZ}$
IC19	6	$(UP + DN)A$
IC19	8	$\overline{UP} \overline{DN} + \overline{A} + F + M$
IC8	2	$WYZ (1 \overline{VDC} \overline{MV} + 10 \overline{MV} + 100 + M\Omega + ab)$
IC8	14	$1 \overline{VDC} \overline{MV} + 10 \overline{MV} + 100 + M\Omega + ab$
IC9	13	$WZ\overline{A}$
IC9	14	$\overline{F} E M$
IC16	3	ab
IC11	13	$VDC \overline{ab}$
Q11	COLLECTOR	$M\overline{H} (C + E)$
Q12	"	F
Q13	"	$M\overline{H} (A + C)$
Q14	"	$M\overline{H} (B + D)$
Q15	"	$\overline{M}$
Q16	"	MA
Q36	"	$\overline{F} E$
Q37	"	$\overline{F} D$
Q38	"	$\overline{F} C$
Q39	"	$\overline{F} B$
Q40	"	$\overline{F} A$
Q41	"	$\overline{WY}$
IC17	16	$\overline{WX\overline{YZ}} + \overline{WX\overline{YZ}}$

Figure 4-15. LOGIC FUNCTIONS (Sheet 1 of 2)

DEVICE	PIN NO.	LOGIC FUNCTION
IC17	15	$\overline{W}\overline{X}\overline{Y}Z + W\overline{X}YZ$
IC17	8	$\overline{W}X\overline{Y}\overline{Z} + W\overline{X}\overline{Y}\overline{Z}$
IC17	9	$\overline{W}\overline{X}YZ + W\overline{X}\overline{Y}Z$
IC17	13	$\overline{W}X\overline{Y}\overline{Z} + W\overline{X}\overline{Y}\overline{Z}$
IC17	14	$\overline{W}X\overline{Y}Z + W\overline{X}YZ$
IC17	11	$\overline{W}X\overline{Y}\overline{Z}$
IC17	12	$\overline{W}X\overline{Y}Z$
IC17	1	$\overline{W}\overline{X}\overline{Y}\overline{Z}$
IC17	2	$\overline{W}\overline{X}\overline{Y}Z$
Q21	COLLECTOR	$\overline{a}\overline{b}$
Q22	"	$\overline{a}b$
Q23	"	$a\overline{b}$
Q24	"	ab
Q6	"	$A\overline{H}$
Q7	"	$B\overline{H}$
Q8	"	$C\overline{H}$
Q9	"	$D\overline{H}$
Q10	"	$E\overline{H}$
Q29	EMITTER	a buffered
Q30	EMITTER	b buffered

Figure 4-15. LOGIC FUNCTIONS (Sheet 2 of 2)

4-39. COMMAND VOLTAGE CHECK

4-40. The presence of proper command voltages is checked in the following test.

- a. Connect the oscilloscope common to the converter as indicated in the preceeding test.
- b. Perform each of the connector pin voltage checks given in Figure 4-18. The voltages should be as indicated.

4-41. RELAY CHECKS

4-42. The truth table (Figure 4-19) will help locate defective relays or associated drive circuits. Assuming there are no errors in the command voltage check, if the voltage across the coil does not appear as indicated on the truth table, the relay drive circuit is at fault. If the coil voltage is correct but the relay fails to respond, then the relay is

defective. Neither side of K4, K5, or K6 is connected to the circuit common.

4-43. SEVERE CONVERTER MALFUNCTIONS

- a. Symptom: Full-scale output with shorted input.
 Procedure: If dc voltage at TP4 and ac voltage on TP3 are zero, then troubleshoot converter output difference amplifier-integrator, Q8, Q9, A2 and associated circuits.

If the dc voltage on TP4 is greater than $\pm 1V$ (normal is less than 10mV) check for defective Q1 through Q7, A1, C11, C20 or associated circuits.

If ac voltage is present on TP3, check for open or shorted feedback circuit or defective component in rectifier amplifier causing oscillation.

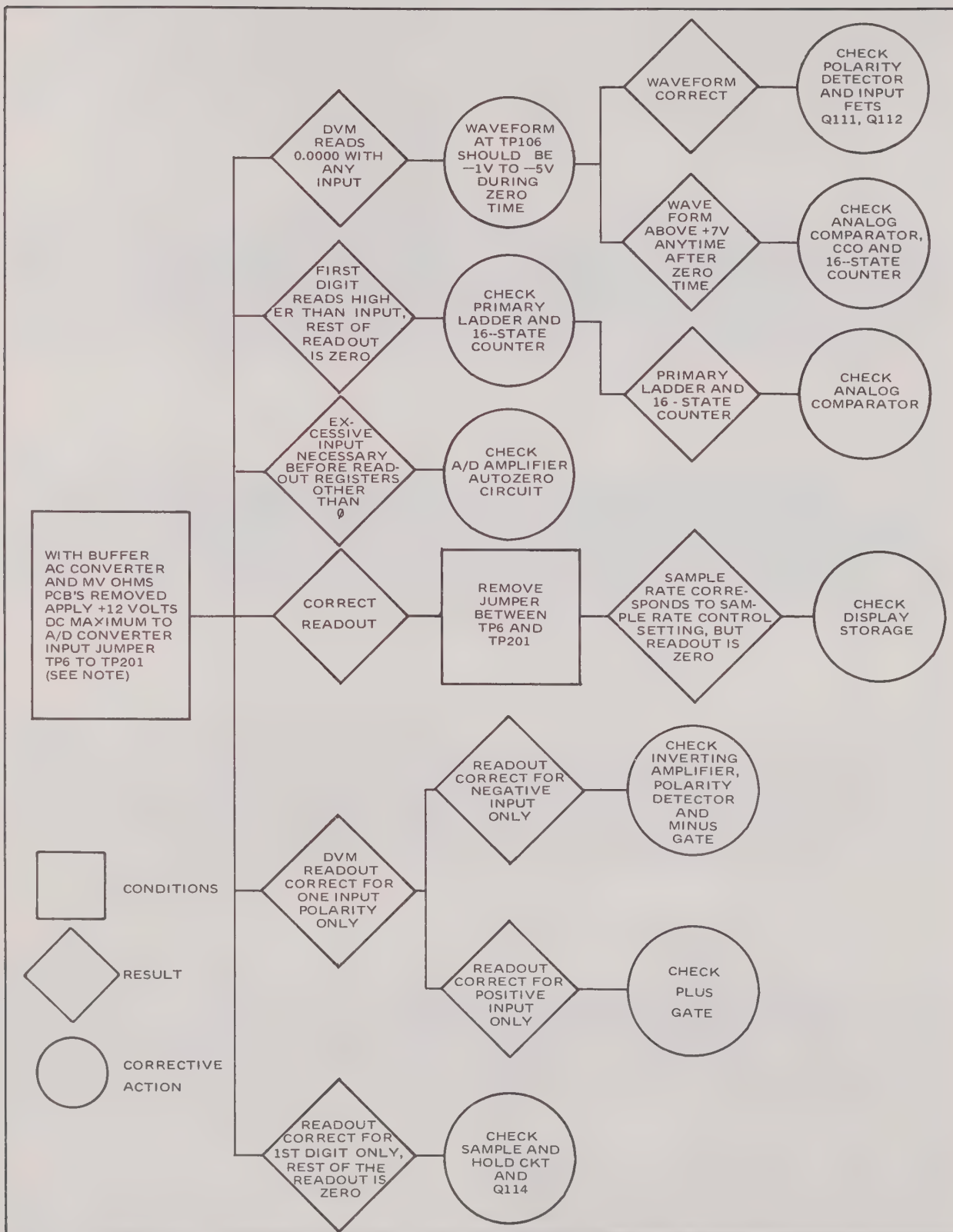


Figure 4-16. TROUBLESHOOTING DMM ANALOG CIRCUITRY

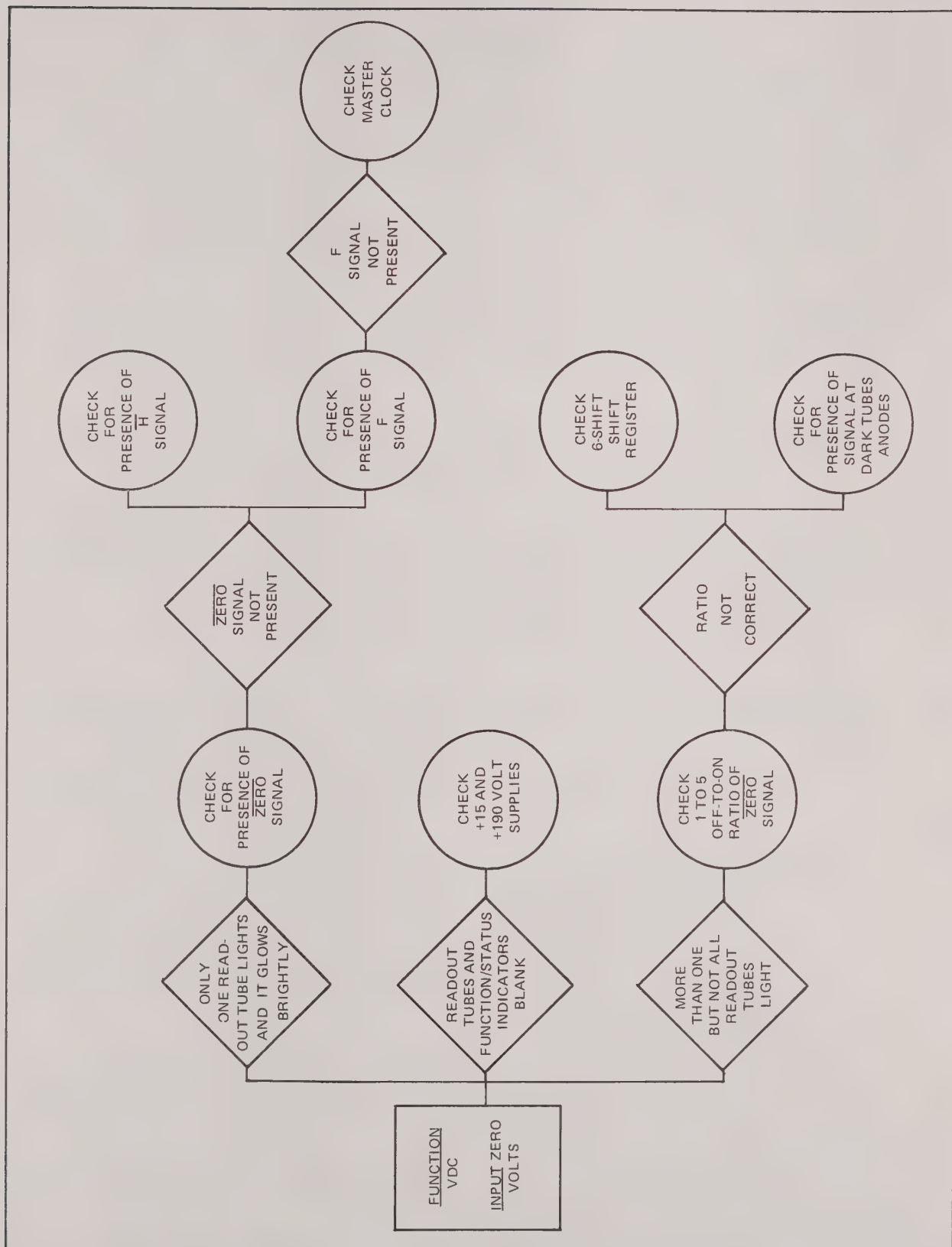


Figure 4-17. TROUBLESHOOTING DMM DISPLAY

PIN NO.	FUNCTION					POSSIBLE TROUBLE
	VAC	VAC	VAC	VAC	ANY EXCEPT VAC	
	RANGE					
	1V	10V	100V	1000V	ANY	
23	<0.6V	>3.0V	<0.6V	>3.0V	<0.6V	1. Improper connections between con- verter board and main frame, e.g., mis- alignment of connector pins.
24	<0.6V	<0.6V	>3.0V	>3.0V	<0.6V	
27	>4.0V	>4.0V	>4.0V	>4.0V	<0.6V	
						2. Faulty function switch on buffer board.
						3. Defect in auto ranging logic, main PCB.
						4. Defective range switch
						5. Short in relay drive circuits on AC option PCB, Q10-Q15, CR7-CR10.
						6. Short between control lines on AC option board.

Figure 4-18. AC CONVERTER FUNCTION COMMAND CHECK

b. Symptom: Zero output with input applied.

Procedure: If ac voltage on TP3 is zero, check for open or short in ac circuit between input and Q1.

If ac voltage does appear on TP3 (full scale is approximately 0.25V RMS), check K3 or troubleshoot output difference amplifier-integrator.

c. Symptom: Range of operation does not correspond to range selected.

Procedure: Make command voltage and relay checks, Figures 4-18 and 4-19.

4-44. MV/Ohms Converter

4-45. This section contains information selected to aid in troubleshooting the MV/Ohms converter. Before attempting to troubleshoot the converter, however, it should be verified that the trouble is actually in the converter and is

not caused by faulty external equipments or improper control settings. For this reason, the performance tests (paragraph 4-19) are suggested as a first step in troubleshooting. The performance tests may also help to localize the trouble to a particular section of the converter.

4-46. SUPPLY VOLTAGE CHECK

4-47. In this test, each of the input supply voltages for the MV/Ohms converter is checked at the input connector. This test verifies only presence of voltages; a detailed check of Model 8350A power supply voltages is given in paragraph 4-31 of the manual.

a. Connect the oscilloscope common to TP3 of the converter. Use the signal at TP4 to externally trigger the oscilloscope. Set the scope controls for dc voltage measurement, and check the following voltages:

CONNECTOR PIN NO.	REQUIRED VOLTAGE
18	-18 volts
16	+18 volts
12	+7 volts

CONVERTER RELAYS	FUNCTION					POSSIBLE TROUBLE
	VAC	VAC	VAC	VAC	ANY EXCEPT VAC	
	RANGE					
	1V	10V	100V	1000V	ANY	
K1	1	1	1	1	0	1. Improper voltages on connector pins, 23, 24, 27 as shown in Figure 4-18. 2. Defective relay. 3. Defective relay drive circuit Q10-Q15.
K2	1	1	1	1	0	
K3	1	1	1	1	0	
K4	0	1	0	0	0	
K5	0	0	1	0	0	
K6	0	0	0	1	0	
Legend: Logical 1 = >4.0V Logical 0 = <0.6V						

Figure 4-19. AC CONVERTER RELAY TRUTH TABLE

CONNECTOR	PIN NO.	FUNCTION	RANGE	REQUIRED VOLTAGE	POSSIBLE TROUBLE
	14	Any function except MVDC	Any	$<0.6v$	1. Improper connections between converter board and main frame, e.g. misalignment of connector pins. 2. Faulty function switches on buffer board.
	14	MVDC	Any	$>4.5v$	
	9	Any function except $10M\Omega$	Any	$<0.6v$	
	9	$10M\Omega$	Any	$>4.5v$	
	5	Any function except $K\Omega$	Any	$<0.6v$	
	5	$K\Omega$	Any	$>4.5v$	
	2	$K\Omega$	1, 10	$>3.0v$	1. Improper connections between converter board and main frame. 2. Defect in autorange logic (main PCB) 3. Defective range switch. CR21 Defective Q10 or A3 Defective
	2	$K\Omega$	100,1000	$<0.6v$	
	1	$K\Omega$	1, 100	$<0.6v$	
	1	$K\Omega$	10,1000	$>3.0v$	
	6	$10M\Omega$	Any	$>4.0v$	
	6	$K\Omega$	100,1000	$>4.0v$	
	6	$K\Omega$	1, 10	$<0.6v$	
	6	VDC	Any	$>4.0v$	
	6	VAC	Any	$<0.6v$	Improper connection between converter board and main frame. Short between VAC line and K8 control line.

Figure 4-20. MV/OHMS CONVERTER FUNCTION COMMAND CHECK

4-48. COMMAND VOLTAGE CHECK

4-49. The presence of proper command voltages is checked in the following test:

- Connect the oscilloscope to the converter as indicated in the preceeding test.
- Perform each of the checks given in Figure 4-20. The voltages should be as indicated.
- Rotate the MV ZERO control on the front panel from fully clockwise to fully counter-clockwise: verify that the voltage at pin 17 of the converter board connector changes from +18 volts to -18 volts.

4-50. MULTIVIBRATOR CHECK

4-51. This test verifies that the multivibrator is working.

- Connect the oscilloscope as indicated in paragraph 4-48 and monitor the waveform at TP4.
- The waveform should be approximately as shown on the MV/Ohms converter schematic.
- If no signal is present, the multivibrator may have stopped due to the oscilloscope probe shorting the drive transistors. Turn the instrument off and then on. If no signal is then present, the multivibrator is defective.
- If the waveform is radically different from the one shown on the schematic, either the drive transistors

(Q6 and Q7) or the modulating/demodulating transistors (Q1 and Q4) are defective.

4-52. RELAY CHECK

4-53. The following truth table (Figure 4-21) is designed to help locate defective relays or associated components. A logical "1" indicates that the relay should be in opposite state from that shown in the schematic. This can be monitored by placing a dc voltmeter or oscilloscope across the coil. If the voltage across the coil is not $> 4\text{v}$ for logic "1" or $> 0.5\text{v}$ for logic "0", the drive relay circuitry is at fault. If the voltage is present but the relay does not change, the relay coil and/or function or range switch is defective.

4-54. TROUBLESHOOTING CHART

4-55. Figure 4-22 describes possible troubles which may be encountered in the MV/Ohms converter together with appropriate troubleshooting procedures.

4-56. CALIBRATION

4-57. The Model 8350A should be calibrated every 24 hours or 90 days, depending on the degree of accuracy to be maintained (see specifications, Section 1), or whenever repairs have been made. Calibration should be done at an ambient room temperature of $20^{\circ}\text{C} \pm 5^{\circ}\text{C}$. Relative humidity should be less than 70%. Refer to Figure 4-1 for recommended test equipment. Adjustment and test point locations are labeled on the top and bottom inner guard covers. Figure 4-23 shows adjustment and test point locations with the top inner guard cover removed.

FUNCTION CALLED	RANGE CALLED	CONVERTER RELAYS								RANGE MVDC		RANGE – KΩ				10MΩ
		K1	K2	K3	K4	K5	K6	K7	K8	100	1000	1	10	100	1000	
MVDC	100	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0
MVDC	1000	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0
KΩ	1	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0
KΩ	10	0	1	1	1	0	1	1	0	0	0	0	1	0	0	0
KΩ	100	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0
KΩ	1000	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0
10MΩ	ANY	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
LEGEND: LOGIC 0 RELAY DE-ENERGIZED (< 0.5v across coil)																
LOGIC 1 RELAY ENERGIZED (> 4.0v across coil)																

SYMPTOM	PROCEDURE
Severe converter malfunction; i.e., full-scale output with shorted input, no output with full-scale input, etc.	Check operational amplifiers, A1 and A2, by measuring their individual inputs and outputs. There should be approximate operational correspondence between input and output levels; however, because the amplifiers are self-protected, only gross errors on the order of 1 or 2 volts should be considered significant.
Readout is zero for an open-circuit input in $K\Omega$ or $10M\Omega$ modes.	Check fuse F1 and relay K3 for opens as follows: - The voltage at the junction of R38 and R39 should be < 200 MV relative to analog common. If the voltage is correct, either relay K2 on the MV/Ohms converter or K8 on the buffer is not working properly. - If the voltage in step (a) is high ($> 1.0v$ dc), then F1 can be checked with a voltmeter to see if it is open. If the same voltage is measured across F1, the fuse should be replaced. - If the fuse is good, measure across the contacts of K3; if the voltage measured in step (a) is also measured across the contacts of K3, the relay switch, coil, or drive circuitry is faulty.
Readout in $K\Omega$ mode is grossly different than measured resistor.	Check relays K5, K6, and K7 and their drivers.
Readout does not change between 100 MV range and 1000 MV range for a valid input signal of approximately 100 MV.	Check relay K8
Gain is approximately 10X too low in 1000 MV range and 100X too low in 100 MV range.	Check relay K4 and its drive circuitry.

Figure 4-22. MV/OHMS CONVERTER TROUBLE CHART

4-58. Preliminary Operations

- Remove the upper and lower dust cover screws, but leave the covers in place.
- Set the 115/230 volt slide switch on the rear panel to 115 and then connect the line cord to the output of an autotransformer set to 120V ac.
- Turn on the Model 8350A and allow it to warm-up for one hour.

4-59. VDC Alignment

- Turn off the instrument and remove the dust covers.
- Turn on the instrument and set the controls as follows:

FUNCTION RANGE	VDC 10
-------------------	-----------

- Connect a shorting jumper between the HI and LO INPUT terminals.

- Connect the shorting bars at the INPUT terminals as follows:

HI INPUT to HI SENSE
LO INPUT to LO SENSE and GUARD

- Connect the input of a dc differential voltmeter to TP205 (high) and TP109 (common).
- Adjust V REF (+7V) for +7.0000V dc at TP205.
- Connect the dc differential voltmeter input to BUFFER ZERO TP2 (high) and TP1 (common).
- Adjust ZERO VDC for a dc differential voltmeter indication of $0 \pm 20 \mu V$. If unable to obtain zero, the range of this adjustment may have to be compensated with jumper selection of R13, R14, and R55 in the A4 Buffer. Before using the following procedure, however, ensure that the A4 Buffer is operating correctly.

- Turn off the instrument and disconnect the dc differential voltmeter.

2. Remove the inner top guard cover.
3. Cut jumpers 1 through 3 on the A4 Buffer and set ZERO VDC (R47) fully counter-clockwise. Refer to Figure 4-23 for jumper locations.
4. Turn on the Model 8350A and repeat step g.
5. Note the readout and polarity indication on the dc differential voltmeter and determine from the following table which jumpers on the A4 Buffer should be connected.

DIFFERENTIAL VOLTMETER INDICATION (MV)	A4 JUMPERS TO CONNECT
+5.9 to +4.4	1, 2
+4.4 to +3.0	2
+3.0 to +1.6	1
+1.6 to +0.1	NONE
+0.1 to -1.3	1, 2, 3
-1.3 to -2.8	2, 3
-2.8 to -4.2	1, 3
-4.2 to -5.7	3

6. Adjust ZERO VDC (R47) for a dc differential voltmeter indication of $0 \pm 20 \mu\text{V}$.
7. Turn off the instrument and disconnect the dc differential voltmeter.
8. Install the top guard cover and turn on the Model 8350A.

9. Repeat steps g and h.

- i. Disconnect the jumper from between the HI and LO INPUT terminals.
- j. Apply the input dc voltages given in the following table and perform the associated adjustments to produce the required readout.

MODEL 8350A INPUT (VDC)	READOUT (DC)	ADJUSTMENT
+0.0010	+0.0010	A-D ZERO
+8.0010	+8.0010	+ CAL
-8.0010	-8.0010	-CAL
+4.0020	+4.0020	LADDER CAL4
+2.0020	+2.0020	LADDER CAL2
+1.0020	+1.0020	LADDER CAL1
+0.9995	+0.9995	REMAINDER CAL

- k. Alternate a dc input to the Model 8350A between 0.9999 and 1.0000V dc and verify that the readout corresponds. If necessary, adjust the COMPARTOR LEVEL control for correct crossover readout.
- l. Repeat steps c through f.
- m. Disconnect the jumper from between the INPUT terminals.

STEP	MODEL 8350A AC INPUT & READOUT	FREQUENCY (kHz)	RANGE	ADJUSTMENT	READOUT TOLERANCE ($\pm$ DIGITS)
1	.00100	50	1	1 MVAC 50 kHz	Adj. for min. reading
2	500.00	1	1000	1000 VAC 1 kHz	5
3	500.00	30	1000	1000 VAC 20 kHz	5
4	1.00000	1	1	1 VAC 1 kHz	10
5	1.00000	50	1	1 VAC 50 kHz	10
6	.00100	1	1	(none)	3
7	.00100	50	1	1 MVAC 50 kHz	Same as step (5)
8	(Repeat steps 4 through 6 as necessary)				
9	10.0000	1	10	10 VAC, 1 kHz	10
10	10.0000	50	10	10 VAC, 50 kHz	10
11	100.000	1	100	100 VAC, 1kHz	10
12	100.000	50	100	100 VAC, 50 kHz	10

Figure 4-24. AC CONVERTER RANGE CALIBRATION

INPUT (VOLTS DC)	RANGE	ADJUSTMENT	READOUT	READOUT DIGIT TOLERANCE
+1.00020	1000	1000 MV	+1000.20	±0
−1.00020	1000	(none)	−1000.10	±2
−0.100020	100	100 MV	+ 100.020	±0
+0.100020	100	(none)	−100.020	±2
+0.050020	100	(none)	+50.020	±2
+0.50020	1000	(none)	+500.20	±2

Figure 4-25. MVDC RANGE CALIBRATION

n. Apply the dc input voltages given in the following table and adjust the associated control for a corresponding readout.

DC INPUT	RANGE	ADJUSTMENT
+10.0010	10	+ CAL
−10.0010	10	−CAL
+100.010	100	100 VDC
+1000.10	1000	1000 VDC

o. Disconnect the test equipment and replace the top dust covers.

4-60. AC Converter Alignment

a. Set the Model 8350A controls as follows:

FUNCTION RANGE	VAC 1000
-------------------	-------------

b. Connect the GUARD terminal to the LO input terminal using the shorting link provided.

c. Short the INPUT terminals together.

d. Connect the differential voltmeter to TP4 with its common connected to TP2. Adjust R30 for zero volts ± 3 millivolts at TP4. Remove the differential voltmeter.

e. Center the front panel AC ZERO control. Adjust coarse AC zero for less than 5 digits on readout.

f. Adjust the AC ZERO control on the front panel for a 0000.00 readout.

g. Remove the short between the INPUT terminals.

h. Perform the checks and adjustments contained in Figure 4-24.

4-61. Calibration of the AC converter is now complete.

4-62. MV/Ohms Converter Alignment

a. Set the Model 8350A controls as follows:

FUNCTION RANGE	MVDC 100
-------------------	-------------

b. Connect the GUARD terminal to the LO INPUT terminal using the shorting link provided with the instrument.

c. Short the INPUT terminals together.

d. Adjust the MV ZERO control on the front panel for a 00.000 ± digit readout.

e. Select the 1000 MVDC RANGE. The readout should be 000.00 ± 1 digit.

f. Remove the short between the INPUT terminals.

g. Perform the checks and adjustments contained in Figure 4-25.

h. Select the 10MΩ and FILTER functions.

- i. Connect the resistances indicated in Figure 4-26 between the INPUT terminals and perform the corresponding adjustment.

NOTE!

The readout indicated in Figure 4-26 should match the exact value of the calibration resistor, not the nominal value.

4-63. Calibration of the MV/Ohms converter is now complete.

INPUT RESISTANCE	RANGE	ADJUSTMENT	READOUT
10M	10 M Ω	MEG Ω	10.0000
1M	1000 K Ω	1000 K	1000.00
100K	100 K Ω	100K	100.000
10K	10 K Ω	10K	10.0000
1K	1 K Ω	1K	1.00000

Figure 4-26. RESISTANCE RANGE CALIBRATION

Section 5

List of Replaceable Parts

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REFERENCE DESIGNATOR	ASSEMBLY NAME	PART NO.	PAGE
	Final Assembly, 8350A Digital Multimeter	317776	5-3
A1	Front Panel Assembly	355958	5-4
A2	Rear Panel Assembly	355941	5-5
A3	Logic/A-D PCB Assembly	356527	5-6
A4	Buffer PCB Assembly	356717	5-25
A5	Function Display PCB Assembly	356725	5-30
—	AC Converter PCB Assembly	270835	5-31
—	Millivolt/Ohms Converter PCB Assembly	270843	5-37

5-1. INTRODUCTION

5-2. This section of the manual contains a listing of replaceable components for this instrument. The first listing contains a complete breakdown of all the major assemblies followed by subsequent listings that itemize the components on each major assembly. An illustration accompanies each major assembly listing to aid in locating the listed components.

5-3. Assemblies and subassemblies are identified by a reference designation beginning with the letter A followed by a number (e.g., A1 etc.). Electrical components appearing on the schematic diagram are identified by their schematic diagram reference designation. Components not appearing on the schematic diagram are consecutively numbered throughout the parts list. These components are identified with whole numbers on the arrow call-out illustrations and by index numbers on the grid illustrations. Flagnotes are used throughout the parts list and refer to special ordering explanations that are located in close proximity to the flagnotes.

5-4. COLUMN DESCRIPTION

- a. The REF DESIG column indexes the item description to the associated illustration. In general the reference designations are listed under each assembly in alpha-numeric order. Subassemblies of minor proportions are sometimes listed with the assembly of which they are a part. In this case, the reference designations for the components of the subassembly may appear out of order.
- b. The INDEX NO. column lists coordinates which locate the designated part on the associated grid illustrations.
- c. The DESCRIPTION column describes the salient characteristics of the component. Indention of the description indicates the relationship to other assemblies, components, etc. In many cases it is necessary to abbreviate in this column. For abbreviations and symbols used, see the following page.
- d. The six-digit part number, by which the item is identified at the John Fluke Mfg. Co., is listed in the STOCK NO. column. Use this number when ordering parts from the factory or authorized representatives.
- e. The Federal Supply Code for the item manufacturer is listed in the MFR column. An abbreviated list of Federal Supply Codes is included in the Appendix.
- f. The part number which uniquely identifies the item to the original manufacturer is listed in the MFR PART NO. column. If a component must be ordered by description, the type number is listed.
- g. The TOT QTY column lists the total quantity of the items used in the instrument and reflects the latest Use Code. Second and subsequent listings of the same item are referenced to the first listing with the abbreviation REF. In the case of optional subassemblies, plug-ins, etc., that are not always part of the instrument or are deviations from the basic instrument model, the TOT QTY column lists the total quantity of the item in that particular assembly.
- h. Entries in the REC QTY column indicate the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of every part in the instrument be stocked. In the case of optional subassemblies, plug-ins, etc., that are not always part of the instrument or are deviations from the basic instrument model, the REC QTY column lists the recommended quantity of the item in that particular assembly.
- i. The USE CODE column identifies certain parts which have been added, deleted or modified during

8350A DIGITAL MULTIMETER, FINAL ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	Parts List to be provided when available						

A1, FRONT PANEL ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	FRONT PANEL ASSEMBLY	355958	89536	355958			
	Window, display	356105	89536	356105	1		
	Corner, handle	295659	89536	295659	2		
	Decal, control nomenclature	357285	89536	357285	1		
	Decal, Fluke	359293	89536	359293	1		
	Binding Post, red	275552	32767	820-65	2		
	Binding Post, black	275560	32767	820-45	2		
	Binding Post, blue	275578	32767	820-55	1		
	Shorting Link	101220	24655	0938-9712	3		

A2, REAR PANEL ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	REAR PANEL ASSEMBLY	355941	89536	355941			
	Connector, ac receptacle	284166	82389	EAC-301	1		
	Power transformer	356196	89536	356196	1		
	Fuse Holder	295741	75915	348-6-9-9	1		
	Fuse, AGC ½A, fast-blo	153858	71400	AGC ½-250V	1		
	Rear Panel (includes slide switch, stock no. 226274)	355974	89536	355974	1		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
A3		LOGIC & A/D P/C ASSEMBLY Figure 5-1	356527	89536	356527	REF		
A1	D5-P2	IC, TTL, dual J-K flip flop	268441	18324	SP322B	6	2	
A2	D5-P5	IC, TTL, dual J-K flip flop	268441	18324	SP322B	REF		
A3	D5-Q2	IC, TTL, dual J-K flip flop	268441	18324	SP322B	REF		
A4	F1-Q4	IC, DTL, dual 4-Input Nand	268383	04713	MC832P	1	1	
A5	H1-P5	IC, TTL, triple 3-Input Nor Gate	268565	18324	SP370A	3	1	
A6	D2-R4	IC, TTL, dual J-K flip flop	268441	18324	SP322B	REF		
A7	D2-R1	IC, TTL, dual J-K flip flop	268441	18324	SP322B	REF		
A8	F2-O4	IC, TTL, dual 4-Input Nor Gate	268557	18324	SP317A	2	1	
A9	H1-P2	IC, TTL, triple 3-Input Nor Gate	268565	18324	SP370A	REF		
A10	F2-O2	IC, TTL, Quad 2-Input Nor Gate	268540	18324	SP380A	3	1	
A11	E3-O4	IC, TTL, triple 3-Input Nor Gate	268565	18324	SP370A	REF		
A12	E3-O2	IC, TTL, dual 4-Input Nor Gate	268557	18324	SP317A	REF		
A13	C4-O2	IC, TTL, Quad 2-Input Nor Gate	268540	18324	SP380A	REF		
A14	I2-Q3	IC, DTL, Quad 2-Input Nand Gate	268375	04713	MC846P	2	1	
A15	C3-N5	IC, DTL, Quad 2-Input Nand Gate	268375	04713	MC846P	REF		
A16	H1-O5	IC, TTL, Quad 2-Input Nor Gate	268540	18324	SP380A	REF		
A17	C3-R3	IC, Decoder driver, DM/SN7441AN, NS8840N	267211	89536	267211	1	1	
A18	C3-O5	IC, TTL, dual J-K flip flop	268441	18324	SP322B	REF		
A19	H1-Q2	IC, DTL, triple 3-Input Nand Gate	266312	04713	MC862P-6909	1	1	
A101	C2-X4	IC, operational amplifier	271502	12040	LM301A	4	1	
A102	F2-X1	IC, operational amplifier	271502	12040	LM301A	REF		
A201	G1-X2	IC, reference amplifier					1	
C1	D5-Q5	Cap, mica, 5600 pf $\pm 2\%$, 500v	182873	14655	CD19F562G	1		
C2	G3-P1	Cap, cer, 0.025 uf $\pm 20\%$, 100v	168435	56289	C023B101H- 253M	2		
C3	F5-R3	Cap, mica, 470 pf $\pm 5\%$, 500v	148429	14655	CD19F471J	1		
C4	F4-R3	Cap, cer, 180 pf $\pm 10\%$, 1 kv	105890	71590	BB60181K- S3N	1		
C5	F1-Q1	Cap, mica, 1500 pf $\pm 5\%$, 500v	148361	14655	CD19F152J	1		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
C6	D1-O5	Cap, cer, 0.0012 uf $\pm 10\%$, 500v	106732	71590	CF-122	1		
C8	C1-N4	Cap, cer, 0.025 uf $\pm 20\%$, 100v	168435	56289	C023B101H- 253M	REF		
C9	C3-R5	Cap, elect, 80 uf $+50/-10\%$, 16v	192914	73445	C426ARE80	1	1	
C10	H1-P3	Cap, cer, 2000 pf, gmv, 1 kv	105569	71590	DA140-139CB	1		
C11	H5-O4	Cap, plstc, 0.1 uf $\pm 10\%$, 250v	161992	73445	C280AE/A 100K	1		
C101	C1-Y2	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	8		
C102	C3-Y2	Cap, mica, 33 pf $\pm 5\%$, 500v	160317	14655	CD15E330J	5		
C103	C1-Y2	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
C105	F3-W4	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
C106	F3-W4	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
C107	F3-X1	Cap, mica, 33 pf $\pm 5\%$, 500v	160317	14655	CD15E330J	REF		
C108	G1-T2	Cap, plstc, 0.047 uf $\pm 2\%$, 100v	170449	84171	1PJ473G	4		
C109	G3-T2	Cap, plstc, 0.047 uf $\pm 2\%$, 100v	170449	84171	1PJ473G	REF		
C110	E2-T4	Cap, cer, 3300 pf $\pm 20\%$, 1kv	106674	56289	C023B102G- 332M	5		
C111	E3-T4	Cap, cer, 3300 pf $\pm 20\%$, 1 kv	106674	56289	C023 B102G 332M	REF		
C112	E4-T4	Cap, cer, 3300 pf $\pm 20\%$, 1 kv	106674	56289	C023B102G 332M	REF		
C113	E4-T4	Cap, cer, 3300 pf $\pm 20\%$, 1 kv	106674	56289	C023B102G 332M	REF		
C114	F1-T4	Cap, cer, 3300 pf $\pm 20\%$, 1 kv	106674	56289	C023B102G 332M	REF		
C115	F5-X2	Cap, plstc, 0.47 uf $\pm 10\%$, 250v	184366	73445	C280AE/A 470K	2		
C116	C5-Y2	Cap, plstc, 0.47 uf $\pm 10\%$, 250v	184366	73445	C280AE/A 470K	REF		
C117	F3-V1	Cap, cer, 15 pf $\pm 10\%$, 500v	159947	00656	Type C1-1	1		
C201	I4-U2	Cap, elect, 8 uf $+150/-10\%$, 350v	275792	14655	BR8-350	1	1	
C202	H3-V3	Cap, elect, 250 uf $+50/-10\%$, 40v	178616	73445	C437ARG250	2	1	
C203	H3-W3	Cap, elect, 50 uf $+50/-10\%$, 25v	168823	73445	C426ARF50	2	1	

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
C204	G3-Y1	Cap, Ta, 1 uf $\pm 20\%$, 35v	161919	56289	196D105X 0035	1		
C205	G1-Y3	Cap, cer, 0.01 uf $+80/-20\%$, 500v	105668	56289	C023B501J 103M	1		
C206	H5-V3	Cap, elect, 250 uf $+50/-10\%$, 40v	178616	73445	C437ARG250	REF		
C207	H3-W1	Cap, elect, 50 uf $+50/-10\%$, 25v	168823	73445	C426ARF50	REF		
C208	H3-S4	Cap, elect, 1600 uf $+50/-10\%$, 10v	272732	73445	C437ARD 1600	4	1	
C209	H3-T2	Cap, elect, 1600 uf $+50/-10\%$, 10v	272732	73445	C437ARD 1600	REF		
C210	H3-T5	Cap, elect, 1600 uf $+50/-10\%$, 10v	272732	73445	C437ARD 1600	REF		
C211	H3-U3	Cap, elect, 1600 uf $+50/-10\%$, 10v	272732	73445	C437ARD 1600	REF		
CR4	G1-Q2	Diode, germanium, 80 ma, 100 piv	149187	93332	1N270	REF		
CR5	C4-Q5	Diode, silicon, 150 ma	203323	03508	DHD1105	33	7	
CR6	B4-N5	Diode, germanium, 80 ma, 100 piv	149187	93332	1N270	REF		
CR7	B4-N5	Diode, germanium, 80 ma, 100 piv	149187	93332	1N270	REF		
CR8	E4-O3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR10	G5-Q1	Diode, germanium, 80 ma, 100 piv	149187	93332	1N270	REF		
CR11	G3-N5	Diode, germanium, 80 ma, 100 piv	149187	93332	1N270	REF		
CR13	F4-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR14	D1-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR15	F1-Q2	Diode, germanium, 80 ma, 100 piv	149187	93332	1N270	REF		
CR16	D1-R2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR101	C2-X1	Diode, silicon, 150 ma, 125 piv	272252	07263	FD333	3	1	
CR102	C2-X1	Diode, silicon, 150 ma, 125 piv	272252	07263	FD333	REF		
CR103	D3-X2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR104	D1-X2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR105	E4-V4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR106	E4-V5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR107	D2-Y2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
CR108	D3-Y2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR109	F5-U2	Diode, silicon, 150 ma, 125 piv	272252	07263	FD333	REF		
CR110	C3-X1	Diode, germanium, 80 ma, 100 piv	149187	93332	1N270	REF		
CR112	D3-T4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR113	D2-T4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR114	C5-T4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR115	C1-T3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR116	E5-U4	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	3	1	
CR118	D2-X2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR119	F3-Y1	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR201	I3-S5	Diode, silicon, 1 amp, 600 piv	112383	05277	1N4822	4	1	
CR202	J1-S5	Diode, silicon, 1 amp, 600 piv	112383	05277	1N4822	REF		
CR203	I3-T1	Diode, silicon, 1 amp, 600 piv	112383	05277	1N4822	REF		
CR204	J1-T1	Diode, silicon, 1 amp, 600 piv	112383	05277	1N4822	REF		
CR205	I3-T4	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	8	2	
CR206	J1-T4	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	REF		
CR207	I3-T5	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	REF		
CR208	J1-T5	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	REF		
CR209	G3-X5	Diode, silicon, 200 ma, 25 piv	190272	93332	1N456A	4	1	
CR212	H1-W4	Diode, silicon, 200 ma, 25 piv	190272	93332	1N456A	REF		
CR213	G5-W4	Diode, silicon, 200 ma, 25 piv	190272	93332	1N456A	REF		
CR214	G4-W4	Diode, silicon, 200 ma, 25 piv	190272	93332	1N456A	REF		
CR215	J1-T2	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	REF		
CR216	I3-T2	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	REF		
CR217	J1-T3	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	REF		
CR218	I3-T3	Diode, silicon, 1 amp, 100 piv	116111	05277	1N4817	REF		
CR219	G1-V2	Diode, zener, 6.3v, 7.5 ma	172148	03877	1N3496	1	1	
Q1	F1-P3	Tstr, silicon, NPN	218396	04713	2N3904	22	5	
Q2	G2-Q5	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q3	F5-Q5	Tstr, silicon, NPN	218396	04713	2N3904	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
Q4	G3-Q5	Tstr, silicon, PNP	195974	04713	2N3906	22	5	
Q5	B3-O2	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q6	E3-P2	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q7	E3-P4	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q8	E3-Q1	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q9	E3-Q4	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q10	E3-Q2	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q11	I3-Q5	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q12	H4-Q5	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q13	I2-Q5	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q14	H5-Q5	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q15	G5-Q5	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q16	H2-Q5	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q17	G3-O2	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q18	G5-O2	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q19	H2-O2	Tstr, FET, N-channel	288324	15818	U1994E	11	2	
Q20	H3-O2	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q21	B3-O4	Tstr, silicon, NPN	245480	07263	S24496	5	1	
Q22	B3-P1	Tstr, silicon, NPN	245480	07263	S24496	REF		
Q23	B5-O4	Tstr, silicon, NPN	245480	07263	S24496	REF		
Q24	B5-P1	Tstr, silicon, NPN	245480	07263	S24496	REF		
	I2-P2							
	I2-P1							
Q27	E5-R2	Tstr, silicon, PNP	195974	04713	2N3906	REF		
	I2-P4							
Q29	J1-R3	Tstr, silicon, NPN	168708	03508	2N3391	8	2	
Q30	J1-R1	Tstr, silicon, NPN	168708	03508	2N3391	REF		
Q31	D1-P2	Tstr, silicon, NPN	218511	95303	60994	7	2	
Q32	D1-Q3	Tstr, silicon, NPN	218511	95303	60994	REF		
Q33	D1-Q1	Tstr, silicon, NPN	218511	95303	60994	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
Q34	D1-P5	Tstr, silicon, NPN	218511	95303	60994	REF		
Q35	D1-P3	Tstr, silicon, NPN	218511	95303	60994	REF		
Q36	C1-P2	Tstr, silicon, PNP	266619	07263	2N4888	5	1	
Q37	C1-Q4	Tstr, silicon, PNP	266619	07263	2N4888	REF		
Q38	C1-Q2	Tstr, silicon, PNP	266619	07263	2N4888	REF		
Q39	C1-Q1	Tstr, silicon, PNP	266619	07263	2N4888	REF		
Q40	C1-P4	Tstr, silicon, PNP	266619	07263	2N4888	REF		
Q41	C1-Q5	Tstr, silicon, NPN	245480	07263	S24496	REF		
Q42	E3-R2	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q43	E3-R3	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q44	H5-Q1	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q45	E1-Q4	Tstr, silicon, unijunction	268110	03508	2N6027	3	1	
Q46	B5-Q2	Tstr, silicon, unijunction	268110	03508	2N6027	REF		
Q101	B5-X4	Tstr, FET, dual, N-channel	257501	17856	DN423	3	1	
Q102	E4-W4	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q103	B4-X2	Tstr, FET, N-channel	271924	07910	CFE13041	4	1	
Q104	C4-X4	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q105	C4-X3	Tstr, FET, N-channel	271924	07910	CFE13041	REF		
Q106	D1-X5	Tstr, silicon, PNP	281758	01295	SKA5153	2	1	
Q107	D2-X5	Tstr, silicon, PNP	281758	01295	SKA5153	REF		
Q108	C2-W1	Tstr, silicon, PNP	195974	14713	2N3906	REF		
Q109	C2-W4	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q110	E5-X4	Tstr, germanium, PNP	182709	01295	GA3938	5	1	
Q111	D4-W4	Tstr, FET, N-channel					1	
Q112	D2-X1	Tstr, FET, N-channel						
Q113	E5-W1	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q114	E5-V4	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q115	F1-W4	Tstr, FET, Dual, N-channel	257501	17856	DN423	REF		
Q116	E4-Y2	Tstr, silicon, PNP	281741	01295	SKA5198	2		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
Q117	F2-X5	Tstr, FET, N-channel	271924	07910	CFE13041	REF		
Q118	F1-X3	Tstr, FET, N-channel	271924	07910	CFE13041	REF		
Q119	E4-X1	Tstr, silicon, PNP	281766	01295	SKA5152	2	1	
Q120	E4-X2	Tstr, silicon, PNP	281766	01295	SKA5152	REF		
Q121	F1-Y2	Tstr, silicon, NPN	220087	03508	12E-1516	1	1	
Q122	E5-Y1	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q123	E5-X5	Tstr, silicon, PNP	281741	01295	SKA5198	REF		
Q124	F2-U4	Tstr, FET, N-channel	261388	04713	SPF179	6	2	
Q125	F2-U2	Tstr, FET, N-channel	261388	04713	SPF179	REF		
Q126	F4-U2	Tstr, FET, N-channel	261388	04713	SPF179	REF		
Q127	F4-U4	Tstr, FET, N-channel	261388	04713	SPF179	REF		
Q128	F1-T2	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q129	E5-T2	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q130	E4-T2	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q131	E2-T2	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q132	E3-T2	Tstr, FET, N-channel	288324	15818	U1994E	REF		
Q133	D3-U1	Tstr, germanium, NPN	182691	01295	GA3937	4	1	
Q134	D2-U2	Tstr, germanium, PNP	182709	01295	GA3938	REF		
Q135	D4-T3	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q136	D1-U1	Tstr, germanium, NPN	182691	01295	GA3937	REF		
Q137	C5-U2	Tstr, germanium, PNP	182709	01295	GA3938	REF		
Q138	D2-T4	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q139	C4-U1	Tstr, germanium, NPN	182691	01295	GA3937	REF		
Q140	C3-U2	Tstr, germanium, PNP	182709	01295	GA3938	REF		
Q141	D1-T4	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q142	C2-U1	Tstr, germanium, NPN	182691	01295	GA3937	REF		
Q143	C1-U2	Tstr, germanium, PNP	182709	01295	GA3938	REF		
Q144	C4-T4	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q145	E5-W3	Tstr, FET, N-channel						
Q146	E4-U3	Tstr, FET, N-channel	261388	04713	SPF179	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
Q147	E2-U3	Tstr, FET, N-channel	261388	04713	SPF179	REF		
Q201	I3-V3	Tstr, silicon, NPN	218511	95303	60994	REF		
Q202	I2-V1	Tstr, silicon, NPN	218511	95303	60994	REF		
Q203	G1-U1	Tstr, silicon, PNP	269076	95303	2N4037	1	1	
Q204	G4-U5	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q205	G1-Y2	Tstr, silicon, PNP	246462	04713	SS7526	1	1	
Q206	G1-Y1	Tstr, silicon, NPN	168708	03508	2N3391	REF		
Q207	G1-X5	Tstr, silicon, NPN	168708	03508	2N3391	REF		
Q208	G1-X3	Tstr, silicon, NPN	168708	03508	2N3391	REF		
Q209	G4-V2	Tstr, silicon, NPN	168708	03508	2N3391	REF		
Q210	G4-V4	Tstr, silicon, NPN	168708	03508	2N3391	REF		
Q211	H1-V3	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q212	H1-V2	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q213	H1-U5	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q214	G3-U1	Tstr, silicon, NPN	150359	95303	2N3053	2	1	
Q215	J2-V2	Tstr, silicon, NPN	170787	95303	2N3054	1	1	
Q216	I4-U5	Tstr, silicon, NPN	150359	95303	2N3053	REF		
Q217	I4-V1	Tstr, silicon, NPN	168708	03508	2N3391	REF		
Q218	G1-Y4	Tstr, FET, N-channel	288324	15818	U1994E	REF		
R1	E1-R1	Res, met flm, 750k $\pm 1\%$, $\frac{1}{2}w$	155192	91637	Type MFF $\frac{1}{2}$	1		
R2	E1-R1	Res, met flm, 110k $\pm 1\%$, $\frac{1}{8}w$	234708	91637	Type MFF $\frac{1}{8}$	1		
R3	D4-Q4	Res, met flm, 46.4k $\pm 1\%$, $\frac{1}{8}w$	188375	91637	Type MFF $\frac{1}{8}$	1		
R4	B3-N5	Res, comp, 470 Ω $\pm 5\%$, $\frac{1}{4}w$	147983	01121	CB4715	4		
R5	F1-P3	Res, comp, 820 Ω $\pm 5\%$, $\frac{1}{4}w$	148015	01121	CB8215	3		
R6	H1-N5	Res, comp, 470 Ω $\pm 5\%$, $\frac{1}{4}w$	147983	01121	CB4715	REF		
R7	G1-R2	Res, comp, 1k $\pm 5\%$, $\frac{1}{4}w$	148023	01121	CB1025	5		
R8	F5-R2	Res, comp, 27k $\pm 5\%$, $\frac{1}{4}w$	148148	01121	CB2735	5		
R9	F4-R2	Res, comp, 10k $\pm 5\%$, $\frac{1}{4}w$	148106	01121	CB1035	6		
R10	G3-R2	Res, comp, 27k $\pm 5\%$, $\frac{1}{4}w$	148148	01121	CB2735	REF		
R11	G2-R2	Res, comp, 4.7k $\pm 5\%$, $\frac{1}{4}w$	148072	01121	CB4725	12		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R12	F1-Q2	Res, comp, 2.7k $\pm 5\%$, $\frac{1}{4}w$	170720	01121	CB2725	6		
R13	F1-P5	Res, comp, 1.5k $\pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	9		
R14	F1-P2	Res, comp, 8.2k $\pm 5\%$, $\frac{1}{4}w$	160796	01121	CB8225	9		
R15	H5-R5	Res, comp, 8.2k $\pm 5\%$, $\frac{1}{4}w$	160796	01121	CB8225	REF		
R16	I3-R2	Res, comp, 1.5k $\pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R17	H3-R2	Res, comp, 1.5k $\pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R18	H4-R2	Res, comp, 2.2k $\pm 5\%$, $\frac{1}{4}w$	148049	01121	CB2225	8		
R19	H4-R2	Res, comp, 22k $\pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	9		
R20	I2-R2	Res, comp, 1.5k $\pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R21	I2-R2	Res, comp, 22k $\pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	REF		
R22	H5-R2	Res, comp, 1.5k $\pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R23	I1-R2	Res, comp, 22k $\pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	REF		
R24	G4-R2	Res, comp, 1.5k $\pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R25	G5-R2	Res, comp, 22k $\pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	REF		
R26	H2-R2	Res, comp, 1.8k $\pm 5\%$, $\frac{1}{4}w$	175042	01121	CB1825	1		
R27	H1-R2	Res, comp, 680 Ω $\pm 5\%$, $\frac{1}{4}w$	148007	01121	CB6815	1		
R28	G2-R2	Res, comp, 1.5k $\pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R29	G1-O1	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	8		
R30	G1-O3	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R31	G1-N5	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R32	G1-O2	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R33	B5-N5	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R35	C1-O2	Res, comp, 2.7k $\pm 5\%$, $\frac{1}{4}w$	170720	01121	CB2725	REF		
R36	B5-N5	Res, comp, 6.8k $\pm 5\%$, $\frac{1}{4}w$	148098	01121	CB6825	2		
R37	C1-O5	Res, comp, 1.2k $\pm 5\%$, $\frac{1}{4}w$	190371	01121	CB1225	3		
R38	C1-O5	Res, comp, 1.2k $\pm 5\%$, $\frac{1}{4}w$	190371	01121	CB1225	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R44	G5-N5	Res, comp, 470 Ω $\pm$ 5%, 1/4w	147983	01121	CB4715	REF		
R45	G4-N5	Res, comp, 1k $\pm$ 5%, 1/4w	148023	01121	CB1025	REF		
R46	H2-R5	Res, comp, 2.2k $\pm$ 5%, 1/4w	148049	01121	CB2225	REF		
R47	G4-R2	Res, comp, 2.2k $\pm$ 5%, 1/4w	148049	01121	CB2225	REF		
R48	B4-R5	Res, comp, 3.9k $\pm$ 5%, 1/4w	148064	01121	CB3925	REF		
R50	E1-R3	Res, comp, 27k $\pm$ 5%, 1/4w	148148	01121	CB2735	REF		
R51	E1-R5	Res, comp, 2.7k $\pm$ 5%, 1/4w	170720	01121	CB2725	REF		
R52	E1-R3	Res, comp, 27k $\pm$ 5%, 1/4w	148148	01121	CB2735	REF		
R53	G2-Q2	Res, comp, 4.7k $\pm$ 5%, 1/4w	148072	01121	CB4725	REF		
R55	H5-R4	Res, comp, 8.2k $\pm$ 5%, 1/4w	160796	01121	CB8225	REF		
R56	C3-R1	Res, comp, 820 Ω $\pm$ 5%, 1/4w	148015	01121	CB8215	REF		
R57	H2-R4	Res, comp, 8.2k $\pm$ 5%, 1/4w	160796	01121	CB8225	REF		
R58	C4-P2	Res, comp, 8.2k $\pm$ 5%, 1/4w	160796	01121	CB8225	REF		
R59	C4-Q3	Res, comp, 8.2k $\pm$ 5%, 1/4w	160796	01121	CB8225	REF		
R60	C4-Q1	Res, comp, 8.2k $\pm$ 5%, 1/4w	160796	01121	CB8225	REF		
R61	C4-P4	Res, comp, 8.2k $\pm$ 5%, 1/4w	160796	01121	CB8225	REF		
R62	C4-P3	Res, comp, 8.2k $\pm$ 5%, 1/4w	160796	01121	CB8225	REF		
R63	C4-Q4	Res, comp, 2.7k $\pm$ 5%, 1/4w	170720	01121	CB2725	REF		
R64	C4-P3	Res, comp, 1.2M $\pm$ 5%, 1/4w	188425	01121	CB1255	5		
R65	C4-Q2	Res, comp, 1.2M $\pm$ 5%, 1/4w	188425	01121	CB1255	REF		
R66	C4-Q1	Res, comp, 1.2M $\pm$ 5%, 1/4w	188425	01121	CB1255	REF		
R67	C4-P5	Res, comp, 1.2M $\pm$ 5%, 1/4w	188425	01121	CB1255	REF		
R68	C4-P4	Res, comp, 1.2M $\pm$ 5%, 1/4w	188425	01121	CB1255	REF		
R69	G2-P2	Res, comp, 4.7k $\pm$ 5%, 1/4w	148072	01121	CB4725	REF		
R70	G1-P2	Res, comp, 4.7k $\pm$ 5%, 1/4w	148072	01121	CB4725	REF		
R71	D4-Q3	Res, comp, 47 Ω $\pm$ 5%, 1/4w	147892	01121	CB4705	2		
R72	H5-P5	Res, comp, 3.9k $\pm$ 5%, 1/4w	148064	01121	CB3925	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R74	H5-P5	Res, comp, $47\Omega \pm 5\%$, $\frac{1}{4}w$	147892	01121	CB4705	REF		
R75	H5-O5	Res, comp, $2.7k \pm 5\%$, $\frac{1}{4}w$	170720	01121	CB2725	REF		
R76	E1-R2	Res, comp, $2.7k \pm 5\%$, $\frac{1}{4}w$	170720	01121	CB2725	REF		
R77	E1-R4	Res, comp, $3.9k \pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R78	I4-R2	Res, comp, $1.5k \pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R79	I4-R2	Res, comp, $1.5k \pm 5\%$, $\frac{1}{4}w$	148031	01121	CB1525	REF		
R80	G1-Q2	Res, comp, $15k \pm 5\%$, $\frac{1}{4}w$	148114	01121	CB1535	REF		
R82	C4-Q3	Res, comp, $820\Omega \pm 5\%$, $\frac{1}{4}w$	148015	01121	CB8215	REF		
R83	G5-N5	Res, comp, $1k \pm 5\%$, $\frac{1}{4}w$	148023	01121	CB1025	REF		
R84	I2-Q4	Res, comp, $470\Omega \pm 5\%$, $\frac{1}{4}w$	147983	01121	CB4715	REF		
R101	B3-Y1	Res, comp, $10k \pm 5\%$, $\frac{1}{4}w$	148106	01121	CB1035	REF		
R102	B5-X1	Res, ww, 10k, factory matched to R103						
R103	C1-X1	Res, ww, 10k, factory matched to R102						
R104	B5-Y1	Res, met flm, $45.3k \pm 1\%$, $1/8w$	234971	91637	Type MFF1/8	3		
R105	B4-Y1	Res, met flm, $45.3k \pm 1\%$, $1/8w$	234971	91637	Type MFF1/8	REF		
R106	B5-Y1	Res, met flm, $49.9k \pm 1\%$, $1/8w$	268821	91637	Type MFF1/8	1		
R107	E2-X3	Res, comp, $4.7k \pm 5\%$, $\frac{1}{4}w$	148072	01121	CB4725	REF		
R108	C2-Y2	Res, comp, $68k \pm 5\%$, $\frac{1}{4}w$	148171	01121	CB6835	5		
R109	C3-Y2	Res, comp, $220\Omega \pm 5\%$, $\frac{1}{4}w$	147959	01121	CB2215	1		
R110	E2-X4	Res, comp, $33k \pm 5\%$, $\frac{1}{4}w$	148155	01121	CB3335	3		
R111	C4-X1	Res, comp, $4.7k \pm 5\%$, $\frac{1}{4}w$	148072	01121	CB4725	REF		
R112	F4-T5	Res, comp, $3.9\Omega \pm 5\%$, $\frac{1}{4}w$	268722	01121	CB39G5	2		
R113	E2-W5	Res, comp, $120\Omega \pm 5\%$, $\frac{1}{4}w$	170712	01121	CB1215	1		
R114	E3-W3	Res, comp, $82\Omega \pm 5\%$, $\frac{1}{4}w$	149484	01121	CB8205	1		
R115	C4-X1	Res, comp, $33k \pm 5\%$, $\frac{1}{4}w$	148155	01121	CB3335	REF		
R116	C5-X1	Res, comp, $33k \pm 5\%$, $\frac{1}{4}w$	148155	01121	CB3335	REF		
R117	D1-Y2	Res, comp, $22k \pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	REF		
R118	D1-Y2	Res, comp, $22k \pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	REF		
R119	D1-X2	Res, comp, $5.6K \pm 5\%$, $\frac{1}{4}w$	148080	01121	CB5625	5		
R120	D2-Y2	Res, comp, $220k \pm 5\%$, $\frac{1}{4}w$	160937	01121	CB2245	8		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R121	D3-Y2	Res, comp, 220k $\pm 5\%$, $\frac{1}{4}w$	160937	01121	CB2245	REF		
R122	E2-T1	Res, comp, 51k $\pm 5\%$, $\frac{1}{4}w$	193334	01121	CB5135	6		
R123	E3-T1	Res, comp, 51k $\pm 5\%$, $\frac{1}{4}w$	193334	01121	CB5135	REF		
R124	E4-T1	Res, comp, 51k $\pm 5\%$, $\frac{1}{4}w$	193334	01121	CB5135	REF		
R125	E5-T1	Res, comp, 51k $\pm 5\%$, $\frac{1}{4}w$	193334	01121	CB5135	REF		
R126	F1-T1	Res, comp, 51k $\pm 5\%$, $\frac{1}{4}w$	193334	01121	CB5135	REF		
R128	E3-U1	Res, met flm, 249k $\pm 1\%$, $\frac{1}{8}w$	268805	91637	Type MFF1/8	REF		
R129	E4-U1	Res, met flm, 499k $\pm 1\%$, $\frac{1}{8}w$	268813	91637	Type MFF1/8	2		
R130	E4-U1	Res, comp, 1M $\pm 5\%$, $\frac{1}{4}w$	182204	01121	CB1055	3		
R131	E5-U1	Res, comp, 2M $\pm 5\%$, $\frac{1}{4}w$	268771	01121	CB2055	2		
R133	D3-U5	Res, ww, 50k, factory matched						
R134	C5-U5	Res, ww, 50k, factory matched						
R135	C3-U5	Res, ww, 100k, factory matched						
R136	C1-U5	Res, ww, 200k, factory matched						
R137	D4-V3	Res, var, ww, 50 Ω $\pm 20\%$, $\frac{1}{4}w$	112490	71450	Type 110	1		
R138	C5-V3	Res, var, ww, 100 Ω $\pm 20\%$, $\frac{1}{4}w$	112797	71450	Type 110	1		
R139	C2-V3	Res, var, ww, 200 Ω $\pm 20\%$, $\frac{1}{4}w$	144766	71450	Type 110	3		
R140	D3-T1	Res, met flm, 32.4k $\pm 1\%$, $\frac{1}{8}w$	182956	91637	Type MFF1/8	4		
R141	D3-T1	Res, met flm, 7.5k $\pm 1\%$, $\frac{1}{8}w$	223529	91637	Type MFF1/8	4		
R142	D4-T1	Res, comp, 11k $\pm 5\%$, $\frac{1}{4}w$	221580	01121	CB1135	5		
R143	D4-T1	Res, comp, 220k $\pm 5\%$, $\frac{1}{4}w$	160937	01121	CB2245	REF		
R144	C5-T1	Res, met flm, 32.4k $\pm 1\%$, $\frac{1}{8}w$	182956	91637	Type MFF1/8	REF		
R145	D1-T1	Res, met flm, 7.5k $\pm 1\%$, $\frac{1}{8}w$	223529	91637	Type MFF1/8	REF		
R146	D1-T1	Res, comp, 39k $\pm 5\%$, $\frac{1}{4}w$	188466	01121	CB3935	1		
R147	D2-T1	Res, comp, 11k $\pm 5\%$, $\frac{1}{4}w$	221580	01121	CB1135	REF		
R148	D2-T1	Res, comp, 11k $\pm 5\%$, $\frac{1}{4}w$	221580	01121	CB1135	REF		
R149	C3-T3	Res, met flm 32.4k $\pm 1\%$, $\frac{1}{8}w$	182956	91637	Type MFF1/8	REF		
R150	C3-T3	Res, met flm, 7.5k $\pm 1\%$, $\frac{1}{8}w$	223529	91637	Type MFF1/8	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R151	C4-T1	Res, comp, 11k $\pm 5\%$, $\frac{1}{4}w$	221580	01121	CB1135	REF		
R152	C4-T1	Res, comp, 220k $\pm 5\%$, $\frac{1}{4}w$	160937	01121	CB2245	REF		
R153	B5-T4	Res, met flm, 32.4k $\pm 1\%$, $\frac{1}{8}w$	182956	91637	Type MFF 1/8	REF		
R154	C1-T4	Res, met flm, 7.5k $\pm 1\%$, $\frac{1}{8}w$	223529	91637	Type MFF 1/8	REF		
R155	C3-T3	Res, comp, 11k $\pm 5\%$, $\frac{1}{4}w$	221580	01121	CB1135	REF		
R156	C2-T3	Res, comp, 220k $\pm 5\%$, $\frac{1}{4}w$	160937	01121	CB2245	REF		
R157	C1-V5	Res, comp, 4.7k $\pm 5\%$, $\frac{1}{4}w$	148072	01121	CB4725	REF		
R158	C1-W2	Res, comp, 47k $\pm 5\%$, $\frac{1}{4}w$	148163	01121	CB4735	9		
R160	C1-W2	Res, comp, 47k $\pm 5\%$, $\frac{1}{4}w$	148163	01121	CB4735	REF		
R161	C1-W3	Res, comp, 4.7k $\pm 5\%$, $\frac{1}{4}w$	148072	01121	CB4725	REF		
R162	C1-W3	Res, comp, 100k $\pm 5\%$, $\frac{1}{4}w$	148189	01121	CB1045	8		
R163	D3-W5	Res, ww, 28.588k, factory matched						
R164	C5-W5	Res, ww, 28.588k, factory matched						
R165	C4-W3	Res, var, ww, $15\Omega \pm 20\%$, $1\frac{1}{4}w$	163634	71450	Type 110	2		
R166	D3-W3	Res, var, ww, $15\Omega \pm 20\%$, $1\frac{1}{4}w$	163634	71450	Type 110	REF		
R169	E2-X5	Res, comp, 47k $\pm 5\%$, $\frac{1}{4}w$	148163	01121	CB4735	REF		
R170	E3-V4	Res, comp, 220k $\pm 5\%$, $\frac{1}{4}w$	160937	01121	CB2245	REF		
R171	E3-W3	Res, met flm, 45.3k $\pm 1\%$, $\frac{1}{8}w$	234971	91637	Type MFF1/8	REF		
R172	E2-Y3	Res, var, ww, $150\Omega \pm 20\%$, $1\frac{1}{4}w$	163642	71450	Type 110	1		
R173	F2-W1	Res, met flm, 21.5k $\pm 1\%$, $\frac{1}{8}w$	168278	91637	Type MFF1/8	1		
R174	F2-W2	Res, met flm, 22.1k $\pm 1\%$, $\frac{1}{8}w$	235234	91637	Type MFF1/8	1		
R175	F2-W2	Res, comp, 820k $\pm 5\%$, $\frac{1}{4}w$	220541	01121	CB8245	1		
R177	F3-X5	Res, comp, 15k $\pm 5\%$, $\frac{1}{4}w$	148114	01121	CB1535	REF		
R178	F3-X3	Res, comp, 1k $\pm 5\%$, $\frac{1}{4}w$	148023	01121	CB1025	REF		
R179	F3-X4	Res, comp, 100k $\pm 5\%$, $\frac{1}{4}w$	148189	01121	CB1045	REF		
R180	E2-X1	Res, comp, 15k $\pm 5\%$, $\frac{1}{4}w$	148114	01121	CB1535	REF		
R181	E2-X2	Res, comp, 100k $\pm 5\%$, $\frac{1}{4}w$	148189	01121	CB1045	REF		
R182	E3-W2	Res, ww, 200k, factory matched						
R183	F4-U1	Res, ww, 1.02k $\pm 0.1\%$, $\frac{1}{2}w$	145128	89536	145128	1		
R184	F3-T4	Res, ww, 5k $\pm 0.03\%$, $\frac{1}{2}w$	195768	89536	195768	1		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R185	F4-T2	Res, var, ww, 200 Ω $\pm$ 20%, 1 $\frac{1}{4}$ w	144766	71450	Type 110	REF		
R186	F3-X4	Res, comp, 10k $\pm$ 5%, $\frac{1}{4}$ w	148106	01121	CB1035	REF		
R187	F3-Y3	Res, comp, 10k $\pm$ 5%, $\frac{1}{4}$ w	148106	01121	CB1035	REF		
R188	E2-X5	Res, comp, 220k $\pm$ 5%, $\frac{1}{4}$ w	160937	01121	CB2245	REF		
R189	F3-Y2	Res, comp, 100k $\pm$ 5%, $\frac{1}{4}$ w	148189	01121	CB1045	REF		
R190	F3-Y2	Res, comp, 100k $\pm$ 5%, $\frac{1}{4}$ w	148189	01121	CB1045	REF		
R191	F3-X5	Res, comp, 1M $\pm$ 5%, $\frac{1}{4}$ w	182204	01121	CB1055	REF		
R192	F3-V3	Res, var, ww, 10k $\pm$ 20%, 1 $\frac{1}{4}$ w	112862	71450	Type 110	2		
R193	F3-U1	Res, comp, 22k $\pm$ 5%, $\frac{1}{4}$ w	148130	01121	CB2235	REF		
R194	A5-X1	Res, var, comp, 100k $\pm$ 30%, $\frac{1}{4}$ w	223149	37942	Type MTC-1	2		
R195	E5-U4	Res, comp, 100k $\pm$ 5%, $\frac{1}{4}$ w	148189	01121	CB1045	REF		
R196	E3-V5	Res, comp, 27k $\pm$ 5%, $\frac{1}{4}$ w	148148	01121	CB2735	REF		
R201	J2-U4	Res, comp, 510 Ω $\pm$ 5%, $\frac{1}{2}$ w	108951	01121	EB5115	1		
R202	I4-W2	Res, comp, 68k $\pm$ 5%, $\frac{1}{4}$ w	148171	01121	CB6835	REF		
R203	I3-W2	Res, met flm, 357k $\pm$ 1%, 1/8w	235002	91637	Type MFF1/8	1		
R204	I2-W2	Res, met flm, 39.2k $\pm$ 1%, 1/8w	236414	91637	Type MFF1/8	1		
R205	G4-W4	Res, comp, 15 Ω $\pm$ 5%, $\frac{1}{4}$ w	147876	01121	CB1505	1		
R206	G1-V1	Res, comp, 3.9M $\pm$ 5%, $\frac{1}{4}$ w	188417	01121	CB3955	1		
R207	G2-U3	Res, comp, 51 Ω $\pm$ 5%, $\frac{1}{2}$ w	144717	01121	EB5105	2		
R208	G1-U5	Res, comp, 5.6k $\pm$ 5%, $\frac{1}{4}$ w	148080	01121	CB5625	REF		
R209	G1-V4	Res, met flm, 30.9k $\pm$ 1%, 1/8w	291500	91637	Type MFF1/8	1		
R210	G3-Y3	Res, comp, 180k $\pm$ 5%, $\frac{1}{4}$ w	193441	01121	CB1845	1		
R211	G3-Y4	Res, comp, 560 Ω , $\pm$ 5%, $\frac{1}{4}$ w	147991	01121	CB5615	1		
R212	G2-X5	Res, met flm, factory selected and matched						
R213	G4-X3	Res, ww, factory selected and matched						
R214	G3-X5	Res, comp, 1.2k $\pm$ 5%, $\frac{1}{4}$ w	190371	01121	CB1225	REF		
R215	G1-V2	Res, met flm, 1.87k $\pm$ 1%, 1/8w	267229	91637	Type MFF1/8	1		
R216	F5-W1	Res, comp, 68k $\pm$ 5%, $\frac{1}{4}$ w	148171	01121	CB6835	REF		
R217	G1-V3	Res, comp, 68k $\pm$ 5%, $\frac{1}{4}$ w	148171	01121	CB6835	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R218	G1-V3	Res, met flm, 19.1k $\pm 1\%$, 1/8w	291518	91637	Type MFF1/8	1		
R219	G3-Y3	Res, comp, 3.9 Ω $\pm 5\%$, 1/4w	268722	01121	CB39G5	REF		
R220	G3-X4	Res, comp, 51k $\pm 5\%$, 1/4w	193334	01121	CB5135	REF		
R221	G3-Y1	Res, met flm, 3.74k $\pm 1\%$, 1/8w	272096	91637	Type MFF1/8	2		
R222	G2-W5	Res, var, ww, 500 Ω $\pm 10\%$, 1 1/4w	112433	71450	Type 110	1		
R223	G1-W1	Res, met flm, 10k $\pm 1\%$, 1/8w	168260	91637	Type MFF1/8	3		
R224	H1-W4	Res, comp, 24k $\pm 5\%$, 1/4w	193425	01121	CB2435	1		
R225	G1-U5	Res, comp, 5.6k $\pm 5\%$, 1/4w	148080	01121	CB5625	REF		
R226	H2-W4	Res, comp, 6.8k $\pm 5\%$, 1/4w	148098	01121	CB6825	REF		
R227	I4-W2	Res, comp, 5.6k $\pm 5\%$, 1/4w	148080	01121	CB5625	REF		
R228	I5-W2	Res, met flm, 10k $\pm 1\%$, 1/8w	168260	91637	Type MFF1/8	REF		
R229	J2-W2	Res, comp, 5.6k $\pm 5\%$, 1/4w	148080	01121	CB5625	REF		
R230	J1-W2	Res, met flm, 42.2k $\pm 1\%$, 1/8w	221655	91637	Type MFF1/8	1		
R231	G1-W1	Res, met flm, 10k $\pm 1\%$, 1/8w	168260	91637	Type MFF1/8	REF		
R232	G3-Y2	Res, comp, 1M $\pm 5\%$, 1/4w	182204	01121	CB1055	REF		
R233	G2-U4	Res, comp, 51 Ω $\pm 5\%$, 1/2w	144717	01121	EB5105	REF		
R234	G4-W2	Res, var, ww, 10k $\pm 20\%$, 1 1/4w	112862	71450	Type 110	REF		
R235	G3-X3	Res, ww, 14k $\pm 0.1\%$, 1/4w	275321	89536	275321	1		
R236	G2-X3	Res, met flm, 3.74k $\pm 1\%$, 1/8w	272096	91637	Type MFF1/8	REF		
S1	A5-U1	Switch Assembly	355255	89536	355255	1		
V1	B1-P2	Tube, Nixie $\text{\textcircled{R}}$, 0-9 Readout	266502	83594	B5750S	6		
V2	B1-P4	Tube, Nixie $\text{\textcircled{R}}$, 0-9 Readout	266502	83594	B5750S	REF		
V3	B1-Q1	Tube, Nixie $\text{\textcircled{R}}$, 0-9 Readout	266502	83594	B5750S	REF		
V4	B1-Q3	Tube, Nixie $\text{\textcircled{R}}$, 0-9 Readout	266502	83594	B5750S	REF		
V5	B1-Q5	Tube, Nixie $\text{\textcircled{R}}$, 0-9 Readout	266502	83594	B5750S	REF		
V6	B1-R3	Tube, Nixie $\text{\textcircled{R}}$, 0-9 Readout	266502	83594	B5750S	REF		
	J3-V1	Heat sink, Q215	270611	89536	270611	1		
		Socket, IC, 14 contact	276527	23880	TSA-2900-14W	12		
		Socket, IC, 16 contact	276535	23880	TSA-2900-16W	7		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	1	A201, R212 and R213 are a matched set and must be replaced as a set. For replacement, order Reference-Amplifier Set, part number 277814.						
	2	Q111, Q112, and Q145 are a J-FET matched set and must be replaced as a set. For replacement, order part number 274795.						
	3	R102 and R103 are a matched set and must be replaced as a set. For replacement, order Inverting Amplifier Resistor Set, part number 277798.						
	4	R133, R134, R135, R136, R163, R164 and R182 are a matched Ladder Divider Resistor Set, part number 277780. However, the resistors may be replaced individually if model, serial number, full reference designation and all information stamped on the old resistor are included when ordering a new one.						

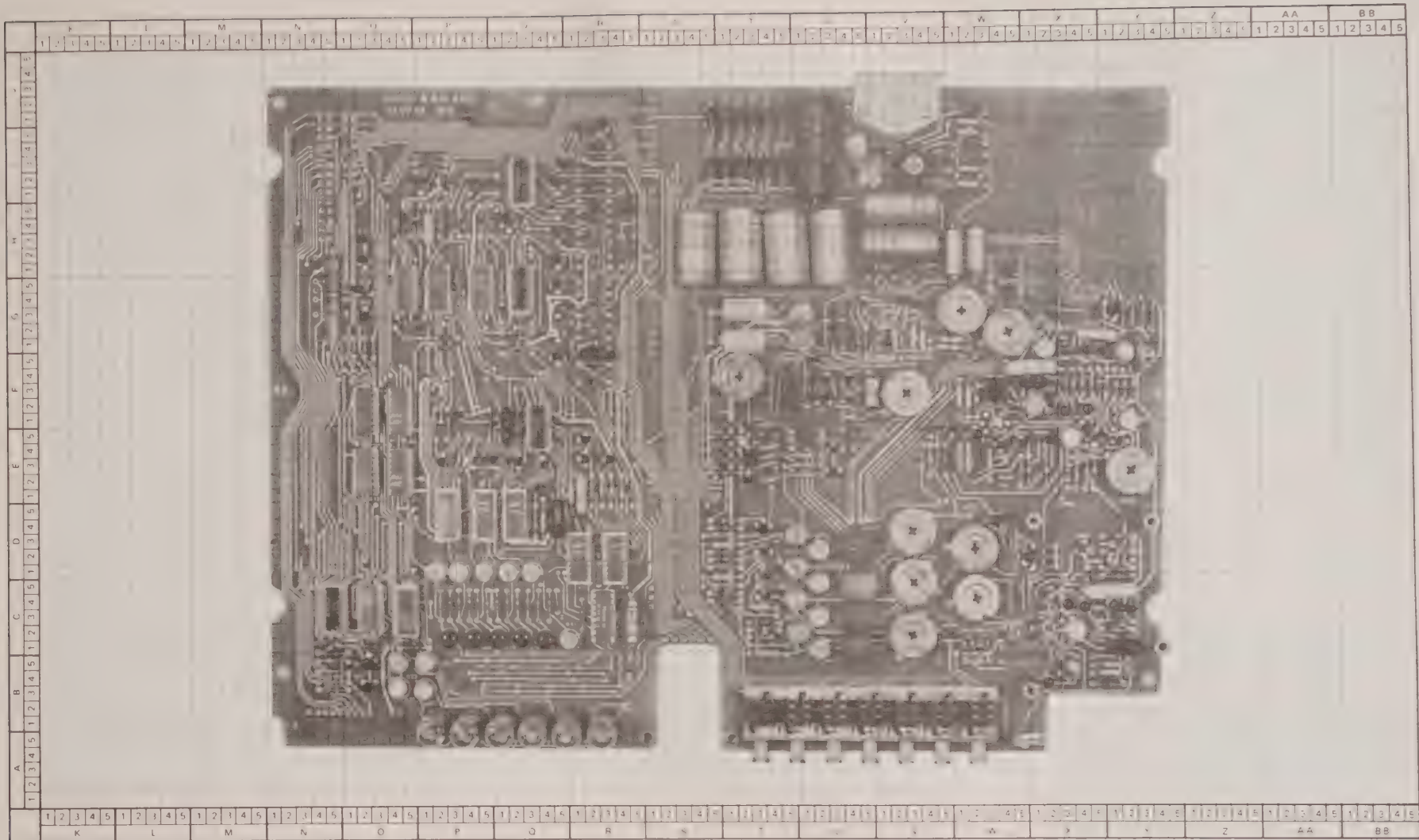


Figure 5-1. LOGIC AND A/D PCB ASSEMBLY

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
A4		BUFFER P/C ASSEMBLY Figure 5-2	356717	89536	356717	REF		
A1	F1-M5	IC, operational amplifier	271502	12040	LM301A	REF	1	
A2	I1-O3	IC, operational amplifier	271502	12040	LM301A	REF		
C1	E3-N4	Cap, mica, 33 pf $\pm 5\%$, 500v	160317	14655	CD15E330J	REF		
C3	G1-M4	Cap, plstc, 0.1 uf $\pm 2\%$, 100v	188706	84171	1PJ104G	3		
C4	F1-M3	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
C5	J1-M4	Cap, plstc, 0.047 uf $\pm 2\%$, 100v	170449	84171	1PJ473G	REF		
C6	J1-M5	Cap, plstc, 0.047 uf $\pm 2\%$, 100v	170449	84171	1PJ473G	REF		
C7	J1-M2	Cap, plstc, 0.1 uf $\pm 2\%$, 100v	188706	84171	1PJ104G	REF		
C8	J1-N2	Cap, plstc, 0.22 uf $\pm 10\%$, 80v	159392	56289	192P2249R8	1		
C9	J1-N4	Cap, plstc, 0.12 uf $\pm 10\%$, 200v	223594	56289	192P12492	1		
C10	G4-O2	Cap, plstc, 0.1 uf $\pm 2\%$, 100v	188706	84171	1PJ104G	REF		
C11	I1-O4	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
C13	E4-M5	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
C14	F2-M3	Cap, mica, 33 pf $\pm 5\%$, 500v	160317	14655	CD15E330J	REF		
C15	I2-O3	Cap, mica, 68 pf $\pm 5\%$, 500v	148510	14655	CD15F680J			
C16	H3-N5	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
CR1	E5-N2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR2	F3-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR3	F2-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR4	F3-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR5	I4-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR6	I4-O4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR7	E1-N2	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	REF		
CR8	E1-N4	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	REF		
CR9	B3-N3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR10	I4-N3	Diode, silidon, 150 ma	203323	03508	DHD1105	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
CR11	I4-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR13	J1-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR14	B5-N3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR15	F5-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR16	F4-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR17	J1-O4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
K1	C3-M4	Reed switch	277020	12617	SRR-3	1		
	C3-N4	Coil, reed switch	269001	71707	SR-6-P	1		
K2	D3-N3	Reed switch	219097	15898	765972	5		
	D5-N3	Coil, reed switch	269019	71707	U-6-P	5		
K3	D3-N1	Reed switch	219097	15898	765972	REF		
	D5-N1	Coil, reed switch	269019	71707	U-6-P	REF		
K4	D3-N5	Reed switch	219097	15898	765972	REF		
	D5-N5	Coil, reed switch	269019	71707	U-6-P	REF		
K7	I4-O3	Reed switch	219097	15898	765972	REF		
	J2-O3	Coil, reed switch	269019	71707	U-6-P	REF		
K8	I4-O1	Reed switch	219097	15898	765972	REF		
	J2-O1	Coil, reed switch	269019	71707	U-6-P	REF		
Q1	E4-N2	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q2	E4-N4	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q3	E4-O1	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q4	E4-N1	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q5	D3-N3	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q6	C5-M4	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q7	D3-M4	Tstr, FET, dual, N-channel	267963	17856	DN503	1	1	
Q8	I1-M2	Tstr, FET, N-channel	271924	07910	CFE13041	REF		
Q9	H3-O2	Tstr, FET, dual, N-channel	257501	17856	DN423	REF		
Q11	F1-M1	Tstr, silicon, NPN	218396	04713	2N3904	REF		
R1	C1-N4	Res, ww, selected & matched	5					

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R2	B5-M4	Res, ww, selected & matched						
R3	B3-M4	Res, ww, selected & matched						
R4	D1-N5	Res, var, ww, 2k $\pm 5\%$, 1/4w	160705	71450	Type 110	1		
R5	B1-N3	Res, ww, 898.84k, matched						
R6	D1-N1	Res, var, ww, 200 Ω $\pm 20\%$, 1/4w	144766	71450	Type 110	REF		
R7	B1-M3	Res, ww, 99.91k, matched						
R8	C5-M3	Res, comp, 220k $\pm 10\%$, 2w	110197	01121	HB2241	2		
R9	C5-M1	Res, comp, 220k $\pm 10\%$, 2w	110197	01121	HB2241	REF		
R10	D5-M4	Res, ww, 33k $\pm 0.1\%$, 1/2w	277921	89536	277921	2		
R11	F5-M3	Res, met flm, 604k $\pm 1\%$, 1/2w	182493	91637	Type MFF 1/2	3		
R12	D5-M5	Res, ww, 33k $\pm 0.1\%$, 1/2w	277921	89536	277921	REF		
R13	D5-M1	Res, met flm, 28.7 Ω $\pm 1\%$, 1/8w	272823	91637	Type MFF 1/8	1		
R14	D5-M2	Res, met flm, 13.7 Ω $\pm 1\%$, 1/8w	272815	91637	Type MFF 1/8	1		
R15	C2-N5	Res, comp, 68k $\pm 5\%$, 1/4w	148171	01121	CB6835	REF		
R16	C2-N2	Res, comp, 100k $\pm 5\%$, 1/4w	148189	01121	CB1045	REF		
R17	C2-M5	Res, comp, 100k $\pm 5\%$, 1/4w	148189	01121	CB1045	REF		
R18	C2-M2	Res, comp, 10k $\pm 5\%$, 1/4w	148106	01121	CB1035	REF		
R21	H3-N5	Res, comp, 47k $\pm 5\%$, 1/4w	148163	01121	CB4735	REF		
R22	F4-N3	Res, comp, 2.2k $\pm 5\%$, 1/4w	148049	01121	CB2225	REF		
R23	I2-M4	Res, met flm, 54.9k $\pm 1\%$, 1/8w	271353	91637	Type MFF 1/8	2		
R24	I2-M4	Res, met flm, 28.7k $\pm 1\%$, 1/8w	235176	91637	Type MFF 1/8	1		
R25	I3-M4	Res, met flm, 54.9k $\pm 1\%$, 1/8w	271353	91637	Type MFF 1/8	REF		
R26	I2-N5	Res, met flm, 499k $\pm 1\%$, 1/8w	268813	91637	Type MFF 1/8	REF		
R28	C3-P1	Res, var, comp, 100k $\pm 30\%$, 1/4w	223149	37942	Type MTC-1	REF		
R32	I1-N2	Res, comp, 30k $\pm 5\%$, 1/4w	193417	01121	CB3035	3		
R33	I1-N2	Res, comp, 47k $\pm 5\%$, 1/4w	148163	01121	CB4735	REF		
R34	E5-N5	Res, comp, 4.7k $\pm 5\%$, 1/4w	148072	01121	CB4725	REF		
R35	I3-N1	Res, met flm, 402k $\pm 1\%$, 1/8w	217984	91637	Type MFF 1/8	1		
R36	I2-N5	Res, comp, 47k $\pm 5\%$, 1/4w	148163	01121	CB4735	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R37	F5-N3	Res, comp, 2.2k $\pm 5\%$, $\frac{1}{4}w$	148049	01121	CB2225	REF		
R38	F1-N5	Res, comp, 4.7k $\pm 5\%$, $\frac{1}{4}w$	148072	01121	CB4725	REF		
R40	F3-N3	Res, comp, 2.2k $\pm 5\%$, $\frac{1}{4}w$	148049	01121	CB2225	REF		
R41	F3-N3	Res, comp, 2.2k $\pm 5\%$, $\frac{1}{4}w$	148049	01121	CB2225	REF		
R42	F5-N3	Res, comp, 2.2k $\pm 5\%$, $\frac{1}{4}w$	148049	01121	CB2225	REF		
R44	H2-04	Res, met flm, 604k $\pm 1\%$, $\frac{1}{2}w$	182493	91637	Type MFF $\frac{1}{2}$	REF		
R45	H3-N4	Res, comp, 47k $\pm 5\%$, $\frac{1}{4}w$	148163	01121	CB4735	REF		
R46	H3-N4	Res, comp, 47k $\pm 5\%$, $\frac{1}{4}w$	148163	01121	CB4735	REF		
R47	E4-M3	Res, var, ww, 10 Ω $\pm 10\%$, 2w	183921	71450	Type 115	1		
R48	F4-M2	Res, comp, 30k $\pm 5\%$, $\frac{1}{4}w$	193417	01121	CB3035	REF		
R49	F3-M2	Res, comp, 30k $\pm 5\%$, $\frac{1}{4}w$	193417	01121	CB3035	REF		
R50	F2-M2	Res, comp, 13k $\pm 5\%$, $\frac{1}{4}w$	221598	01121	CB1335	1		
R51	F1-N5	Res, comp, 47k $\pm 5\%$, $\frac{1}{4}w$	148163	01121	CB4735	REF		
R52	F2-N3	Res, comp, 4.7k $\pm 5\%$, $\frac{1}{4}w$	148072	01121	CB4725	REF		
R54	B3-N5	Res, ww, selected & matched						
R55	D5-M2	Res, comp, 6.2 Ω $\pm 5\%$, $\frac{1}{4}w$	272831	01121	CB62G5	1		
R56	I1-05	Res, comp, 1k, $\frac{1}{4}w$, 5%	148023	01121	CB1025	1		
S1	F1-P4	Switch Assembly	268656	89536	268656	1		



R1, R2, R3, R5, R7 and R54 are a factory matched set. For replacement, order Input Attenuator Resistor Set, part number 277806.

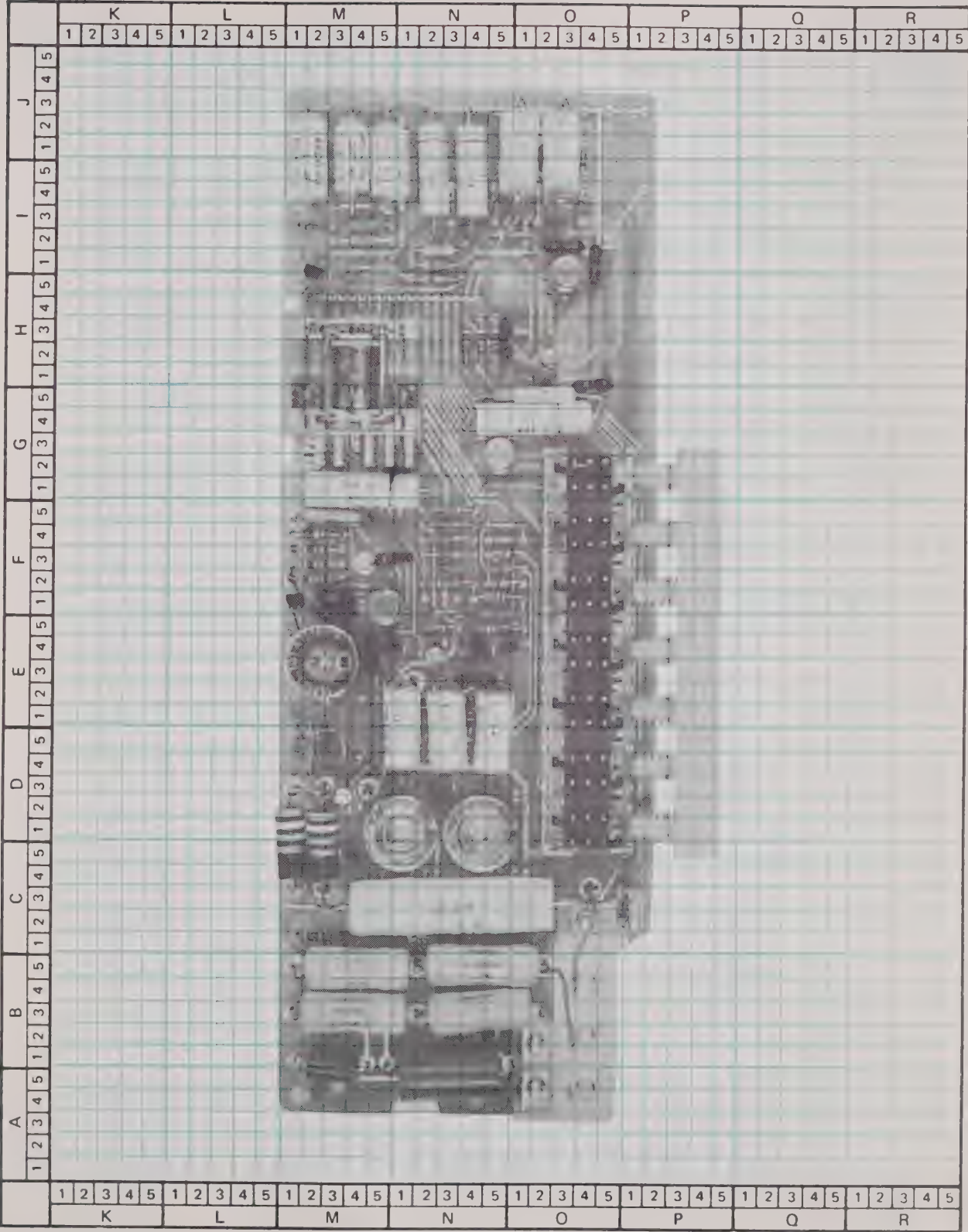


Figure 5-2. BUFFER PCB ASSEMBLY

A5, FUNCTION DISPLAY PCB ASSEMBLY

REF DESIG OR ITEM NO.	DESCRIPTION	FLUKE STOCK NO.	MFG FED SPLY CDE	MFG PART NO. OR TYPE	TOT QTY	REC QTY	USE CDE
	FUNCTION/DISPLAY PCB ASSEMBLY	356725	89536	356725			
	Lamp, incandescent	272476	08108	USASI7209	7	14	

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
		AC Converter PCB Assembly Figure 5-3	270835	89536	270835	1		
A1	E3-M4	IC, 5-Transistor Array	248906	95303	CA3046	1	1	
A2	I3-O3	IC, operational amplifier	271502	12040	LM301A	1	1	
C1	A5-O1	Cap, plstc, 0.22 uf $\pm 20\%$, 1200v	220079	84411	Type JF17	1		
C2	B4-N4	Cap, var, teflon, 0.25 - 1.5 pf, 2kv	273151	74970	Type 273-1-2	1		
C3	C4-N5	Cap, var, 0.8 - 10 pf, 250v	193912	91293	JMC-2950	2		
C4	D1-O3	Cap, var, 0.8 - 10 pf, 250v	193912	91293	JMC-2950	REF		
C5	C3-O3	Cap, mica, 12 pf $\pm 5\%$, 500v	175224	14655	CD15E120J	1		
C6	D5-O3	Cap, var, ceramic, 9 - 35 pf, 200v	153080	72982	538-028D9-35	2		
C7	D3-O3	Cap, mica, 150 pf $\pm 1\%$, 500v	226134	14655	CD15F151-F500	1		
C8	E3-O3	Cap, mica, 4700 pf $\pm 5\%$, 500v	208975	84171	DM19472J	1		
C9	D1-M5	Cap, Ta, 4.7 uf $\pm 20\%$, 20v	161943	56289	196D475X-0020	3	1	
C10	E1-M4	Cap, Ta, 4.7 uf $\pm 20\%$, 20v	161943	56289	196D475X-0020	REF		
C11	D5-N1	Cap, elect, 50 uf $+50/-10\%$, 25v	168823	73445	C426ARF50	1	1	
C12	G1-M5	Cap, cer, 500 pf $\pm 10\%$, 1kv	105692	56289	C067B102E501K	2		
C13	G1-N1	Cap, cer, 500 pf $\pm 10\%$, 1kv	105692	56289	C067B102E501K	REF		
C14	E4-N3	Cap, Ta, 4.7 uf $\pm 20\%$, 20v	161943	56289	196D475X-0020	REF		
C15	F2-O4	Cap, elect, 20 uf $\pm 50/-10\%$, 16v	241356	73445	C426ARE20	1	1	
C16	F2-N1	Cap, cer, 0.01 uf $\pm 20\%$, 100v	149153	56289	C023B101-F103M	2		
C17	F2-N2	Cap, cer, 0.01 uf $\pm 20\%$, 100v	149153	56289	C023B101-F103M	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
C18	G1-O3	Cap, var, ceramic, 9-35 pf, 200v	153080	72982	538-028D9-35	REF		
C19	G5-O4	Cap, plstc, 2 uf $\pm 20\%$, 200v matched						
C20	H3-O4	Cap, plstc, 2 uf $\pm 20\%$, 200v matched						
C21	I2-O1	Cap, plstc, 0.027 uf $\pm 10\%$, 250v	267120	73445	C280AE/A 27K	2		
C22	G5-N2	Cap, plstc, 2 uf $\pm 20\%$, 200v matched						
C23	H3-N2	Cap, plstc, 2 uf $\pm 20\%$, 200v matched						
C24	I3-N5	Cap, plstc, 0.027 uf $\pm 10\%$, 250v	267120	73445	C280AE/A 27K	REF		
C25	J3-P1	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	2		
C26	J3-O4	Cap, mica, 390 pf $\pm 5\%$, 500v	148437	14655	CD15F391J	REF		
C27	J3-O5	Cap, mica, 33 pf $\pm 5\%$, 500v	160317	14655	CD15E330J	1		
C28	D2-O3	Cap, mica, 47 pf $\pm 5\%$, 500v	148536	14655	CD15E470J	1		
C29	C4-N3	Cap, cer, 3 pf $\pm 10\%$, 500v	226316	00656	Type C1-1	1		
CR1	C4-N2	Diode, silicon, 100 ma at 1.5v	261370	22767	S1330	4	4	
CR2	C3-N2	Diode, silicon, 100 ma at 1.5v	261370	22767	S1330	REF		
CR3	G1-N1	Diode, silicon, 100 ma at 1.5v	261370	22767	S1330	REF		
CR4	G1-N2	Diode, silicon, 100 ma at 1.5v	261370	22767	S1330	REF		
CR5	G2-N5	Diode, silicon, 100 ma at 1.5v	161810	07910	CD8606	2	2	
CR6	G1-O1	Diode, silicon, 100 ma at 1.5v	161810	07910	CD8606	REF		
CR7	B2-M5	Diode, silicon, 150 ma	203323	03508	DHD1105	4	2	
CR8	D2-N4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR9	E4-O1	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR10	D5-N4	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR11	I1-O3	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	1	1	
CR12	I1-O4	Diode, zener, 13v	110726	07910	IN964B	1	1	
	B3-P1	Reed switch	284091	12617	Type MRR5	1	1	
	B3-O1	Coil, reed switch	269019	71707	U-6-P	5	1	
K2	B4-M4 B2-M4	Reed switch Coil, reed switch	219097 269019	15898 71707	765972 U-6-P	6 REF	2	

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
K3	J1-P2 J1-O5	Reed switch Coil, reed switch	219097 269019	15898 71707	765972 U-6-P	REF REF		
K4	D2-O2 D1-N4	Reed switch Coil, reed switch	219097 269019	15898 71707	765972 U-6-P	REF REF		
K5	D4-N2 D4-N4	Reed switch Coil, reed switch	219097 269019	15898 71707	765972 U-6-P	REF REF		
K6	E1-O2 E1-N4	Reed switch Coil, reed switch	219097 272070	15898 71707	765972 UD-6-P	REF 1	1	
Q1	D1-N1	Tstr, FET, N-channel	246066	04713	EL131	1	1	
Q2	D1-M4	Tstr, silicon, NPN	218081	04713	MPS6520	2	2	
Q3	F5-N4	Tstr, silicon, PNP	229898	04713	MPS6522	4		
Q4	G1-N4	Tstr, silicon, PNP	229898	04713	MPS6522	REF		
Q5	G2-N4	Tstr, silicon, PNP	229898	04713	MPS6522	REF		
Q6	F5-O1	Tstr, silicon, NPN	218081	04713	MPS6520	REF		
Q7	F5-O3	Tstr, silicon, PNP	229898	04713	MPS6522	REF		
Q8	I4-N5	Tstr, silicon, NPN	218396	04713	2N3904	7	2	
Q9	I1-N5	Tstr, FET, dual, N-channel	267963	17856	DN503	1	1	
Q10	F2-P2	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q11	F3-P2	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q12	F1-P1	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q13	F3-P1	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q14	F3-O5	Tstr, silicon, NPN	218396	04713	2N3904	REF		
Q15	F2-O5	Tstr, silicon, NPN	218396	04713	2N3904	REF		
R1	C2-M5	Res, met flm, 1.11M $\pm 0.1\%$, 1w, matched						
R2	C5-N4	Res, met flm, 267k $\pm 0.1\%$, 1/4w, matched						
R3	C3-P1	Res, var, ww, 1.5k $\pm 10\%$, 1 1/4w	156398	71450	Type 110	1		
R4	C2-O3	Res, ww, 29.53k $\pm 0.1\%$, 1/2w	277657	89536	277657	1	1	
R5	C5-P1	Res, var, ww, 150 Ω $\pm 20\%$, 1 1/4w	163642	71450	Type 110	1		
R6	E2-O5	Res, ww, 2.573k $\pm 0.1\%$, 1/2w	277665	89536	277665	1	1	
R7	D5-P1	Res, var, ww, 15 Ω $\pm 20\%$, 1 1/4w	163634	71450	Type 110	1		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R8	E4-O2	Res, ww, $143.7\Omega \pm 0.1\%$, $\frac{1}{4}w$	277640	89536	277640	1	1	
R9	I4-P1	Res, var, ww, $10k \pm 20\%$, $\frac{1}{4}w$	112862	71450	Type 110	1		
R10	C3-N2	Res, met flm, $32.4k \pm 1\%$, $\frac{1}{8}w$	182956	91637	Type MFF1/8	2		
R11	D4-M4	Res, comp, $8.2k \pm 5\%$, $\frac{1}{4}w$	160796	01121	CB8225	1		
R12	D4-M5	Res, met flm, $32.4k \pm 1\%$, $\frac{1}{8}w$	182956	91637	Type MFF1/8	REF		
R13	E3-N1	Res, met flm, $4.22k \pm 1\%$, $\frac{1}{8}w$	168245	91637	Type MFF1/8	1		
R14	D4-M4	Res, comp, $39k \pm 5\%$, $\frac{1}{4}w$	188466	01121	CB3935	1		
R15	F2-M5	Res, comp, $120k \pm 5\%$, $\frac{1}{4}w$	193458	01121	CB1245	2		
R16	F2-M4	Res, comp, $11k \pm 5\%$, $\frac{1}{4}w$	221580	01121	CB1135	2		
R17	F2-M4	Res, comp, $11k \pm 5\%$, $\frac{1}{4}w$	221580	01121	CB1135	REF		
R18	F2-N1	Res, comp, $120k \pm 5\%$, $\frac{1}{4}w$	193458	01121	CB1245	REF		
R19	G1-M4	Res, comp, $47\Omega \pm 5\%$, $\frac{1}{4}w$	147892	01121	CB4705	2		
R20	G1-M4	Res, comp, $47\Omega \pm 5\%$, $\frac{1}{4}w$	147892	01121	CB4705	REF		
R21	E3-N1	Res, met flm, $84.5k \pm 1\%$, $\frac{1}{8}w$	229492	91637	Type MFF1/8	1		
R22	E4-N4	Res, comp, $15k \pm 5\%$, $\frac{1}{4}w$	148114	01121	CB1535	1		
R23	E4-N3	Res, met flm, $82.5k \pm 1\%$, $\frac{1}{8}w$	246223	91637	Type MFF1/8	1		
R24	F3-N3	Res, met flm, $10k \pm 1\%$, $\frac{1}{8}w$	168260	91637	Type MFF1/8	1		
R25	F3-N3	Res, met flm, $21.5k \pm 1\%$, $\frac{1}{8}w$	168278	91637	Type MFF1/8	2		
R26	F3-N4	Res, met flm, $590\Omega \pm 1\%$, $\frac{1}{8}w$	261883	91637	Type MFF1/8	1		
R27	F3-O1	Res, met flm, $21.5k \pm 1\%$, $\frac{1}{8}w$	168278	91637	Type MFF1/8	REF		
R28	F3-N5	Res, met flm, $10.5k \pm 1\%$, $\frac{1}{8}w$	234096	91637	Type MFF1/8	1		
R29	F3-N5	Res, met flm, $1.27k \pm 1\%$, $\frac{1}{8}w$	267369	91637	Type MFF1/8	1		
R30	I3-N2	Res, var, car, $100k \pm 30\%$, $\frac{1}{4}w$	281675	71450	Type 201	2		
R31	G1-N3	Res, comp, $10M \pm 5\%$, $\frac{1}{4}w$	194944	01121	CB1065	1		
R32	F3-O2	Res, met flm, $40.2k \pm 1\%$, $\frac{1}{8}w$	235333	91637	Type MFF1/8	2		
R33	E4-N2	Res, met flm, $40.2k \pm 1\%$, $\frac{1}{8}w$	235333	91637	Type MFF1/8	REF		
R34	F2-O2	Res, comp, $22k \pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	2		
R35	F2-O3	Res, comp, $2.2k \pm 5\%$, $\frac{1}{4}w$	148049	01121	CB2225	3		
R36	G4-O1	Res, ww, $564.5\Omega \pm 0.1\%$, $\frac{1}{4}w$	277632	89536	277632	2	1	
R37	G3-O2	Res, ww, $564.5\Omega \pm 0.1\%$, $\frac{1}{4}w$	277632	89536	277632	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R38	E3-O5	Res, ww, 125 Ω $\pm$ 0.1%, 1/4w	249284	89536	249284	1	1	
R39	G3-O4	Res, ww, 40k $\pm$ 0.1%	271403	89536	271403	6	2	
R40	H1-O4	Res, ww, 40k $\pm$ 0.1%	271403	89536	271403	REF		
R41		Res, ww, 20k $\pm$ 0.1% (mounted on back)	271395	89536	271395	2	1	
R42	H5-O3	Res, ww, 1M $\pm$ 0.1%	271411	89536	271411	2	1	
R43	G3-N2	Res, ww, 40k $\pm$ 0.1%	271403	89536	271403	REF		
R44	H1-N2	Res, ww, 40k $\pm$ 0.1%	271403	89536	271403	REF		
R45		Res, ww, 20k $\pm$ 0.1% (mounted on back)	271395	89536	271395	REF		
R46	I1-N3	Res, ww, 1M $\pm$ 0.1%	271411	89536	271411	REF		
R47	I3-M5	Res, met flm, 487k $\pm$ 1%, 1/8w	237206	91637	Type MFF 1/8	1		
R48	I3-M4	Res, met flm, 24.3k $\pm$ 1%, 1/8w	236745	91637	Type MFF 1/8	1		
R49	I3-M5	Res, met flm, 100 Ω $\pm$ 1%, 1/8w	168195	91637	Type MFF 1/8	1		
R50	J2-N2	Res, met flm, 30.9k $\pm$ 1%, 1/8w	235275	91637	Type MFF 1/8	1		
R51	J2-N2	Res, met flm, 2.87k $\pm$ 1%, 1/8w	185629	91637	Type MFF 1/8	1		
R52	J2-N3	Res, met flm, 1k $\pm$ 1%, 1/8w	168229	91637	Type MFF 1/8	1		
R53	J3-M5	Res, var, cer, 100k $\pm$ 30%, 1/4w	281675	71450	Type 201	REF		
R54	J2-N5	Res, ww, 40k $\pm$ 0.1%	271403	89536	271403	REF		
R55	J2-O2	Res, ww, 40k $\pm$ 0.1%	271403	89536	271403	REF		
R56	G1-P2	Res, comp, 4.7k $\pm$ 5%, 1/4w	148072	01121	CB4725	4		
R57	G1-P2	Res, comp, 4.7k $\pm$ 5%, 1/4w	148072	01121	CB4725	REF		
R58	G1-P1	Res, comp, 4.7k $\pm$ 5%, 1/4w	148072	01121	CB4725	REF		
R59	G1-P1	Res, comp, 4.7k $\pm$ 5%, 1/4w	148072	01121	CB4725	REF		
R60	G1-O5	Res, comp, 2.2k $\pm$ 5%, 1/4w	148049	01121	CB2225	REF		
R61	G1-O5	Res, comp, 2.2k $\pm$ 5%, 1/4w	148049	01121	CB2225	REF		
R62	I3-O4	Res, comp, 22k $\pm$ 5%, 1/4w	148130	01121	CB2235	REF		



C19, C20, C22 & C23 are a matched set and must be replaced as a set. For replacement, order capacitor set, part number 270470.



R1 and R2 are matched and must be replaced as a set. For replacement order resistor set, part number 269092.

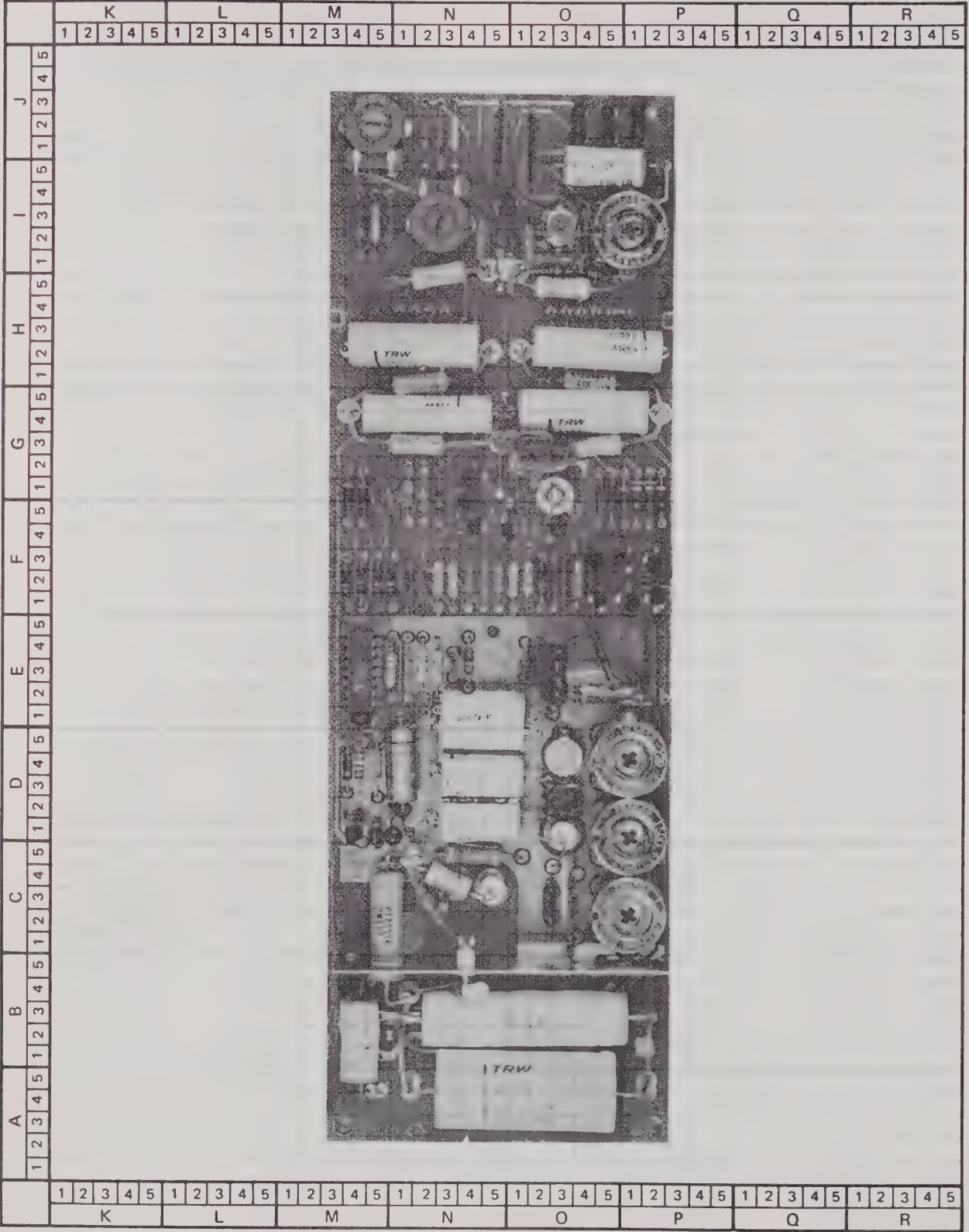


Figure 5-3. AC CONVERTER PCB ASSEMBLY

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
		Millivolt/Ohms Converter P/C Assembly (See Figure 6-11)	270843	89536	270843	1		
A1	F5-P1	IC, operational amplifier	271502	12040	LM301A	2	1	
A2	J1-P1	IC, operational amplifier	271502	12040	LM301A	REF		
A3	J1-M5	IC, transistor array	248906	95303	CA3046	1	1	
C1	C1-O5	Cap, plstc, 0.1uf±20%, 120v	167460	84411	Type JF39	1		
C2	C1-P2	Cap, plstc, 0.22 uf ±20%, 120v	167452	84411	Type JF39	1		
C3	E2-P2	Cap, plstc, 0.01 uf ±20%, 100v	235390	84411	Type 663UW	3	3	
C4	E2-P1	Cap, plstc, 0.01 uf ±20%, 100v	235390	84411	Type 663UW	REF		
C5	G3-P2	Cap, Ta, 1 uf ±20%, 35v	161919	56289	196D105X 0035	1	1	
C6	G2-P1	Cap, mica, 33 pf ±5%, 500v	160317	14655	CD15E330J	2		
C7	F4-P1	Cap, mica, 10 pf ±10%, 500v	175216	14655	CD15C0 100K	2		
C8	I1-P1	Cap, plstc, 0.47 uf ±10%, 250v	184366	73445	C280AE/ A470K	1	1	
C9	I3-P1	Cap, plstc, 0.22 uf ±10%, 250v	194803	73445	C280AE/ A220K	1	1	
C10	J2-O4	Cap, cer, 0.22 uf +80/-20%, 3v	153015	56289	C052B3R0 E224Z	1		
C11	J3-O5	Cap, plstc, 2.2uf±10%, 250v	306522	73445	C280MCH/A2M2	1	1	
C12	J2-P3	Cap, mica, 33 pf ±5%, 500v	160317	14655	CD15E33 0J	REF		
C13	E1-O3	Cap, plstc, 0.1 uf ±10%, 250v	161992	73445	C280AE/A 100K	1	1	
C14	J2-O1	Cap, mica, 3900 pf ±5%, 500v	160325	14655	CD19F392J	1		
C15	J1-O1	Cap, mica, 5600 pf ±2%, 500v	182873	14655	CD19F562G	1		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
C16	E2-O1	Cap, plstc, 0.01 uf $\pm 20\%$, 100v	235390	84411	Type 663UW	REF		
C17	F4-P1	Cap, mica, 10 pf $\pm 10\%$, 500v	175216	14655	CD15C0 100K	REF		
CR1	D1-O3	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	6	4	
CR2	D1-O3	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	REF		
CR3	D2-O2	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	REF		
CR4	D3-O2	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	REF		
CR5	I5-O4	Diode, zener, 6.2v	180497	07910	1N753	2		
CR6	I5-P1	Diode, zener, 6.2v	180497	07910	1N753	REF		
CR7	E1-N4	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	REF		
CR8	E1-N1	Diode, silicon, 75 ma, 100 piv	260554	07910	CD55105	REF		
CR9	D5-N4	Diode, zener, 20v	291575	12969	UZ8720	2		
CR10	D5-N1	Diode, zener, 20v	291575	12969	UZ8720	REF		
CR11	I2-N3	Diode, silicon, 150 ma	203323	03508	DHD1105	15	5	
CR12	I2-M5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR13	E4-N1	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR14	E4-N3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR15	C1-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR16	E4-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR17	F3-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR18	F5-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR19	F3-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR20	C2-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR21	I4-N3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR22	F5-N5	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR23	I3-N3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR24	I4-N3	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
CR25	B5-O2	Diode, silicon, 150 ma	203323	03508	DHD1105	REF		
F1	D4-M5	Fuse, pigtail, 50 ma, 125v (1 provided as a spare)	272088	75915	279.050	2	5	
K1	C4-N4	Relay, dpdt, 5 vdc	268995	24796	R40-E025-2	2	2	
K2	F2-N4	Reed switch	219097	15898	765972	5	5	
	F4-N4	Coil, reed switch	269019	71707	U-6-P	6	6	

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
K3	B1-M5	Reed switch	284091	12617	Type MRR5	1	1	
	B4-M5	Coil, reed switch	269019	71707	U-6-P	REF		
K4	B3-N4	Relay, dpdt, 5 vdc	268995	24796	R40-E025-2	REF		
K5	E2-N4	Reed switch	219097	15898	765972	REF		
	E4-N4	Coil, reed switch	269019	71707	U-6-P	REF		
K6	F1-M5	Reed switch	219097	15898	765972	REF		
	E4-M5	Coil, reed switch	269019	71707	U-6-P	REF		
K7	F1-N2	Reed switch	219097	15898	765972	REF		
	E4-N2	Coil, reed switch	269019	71707	U-6-P	REF		
K8	F2-O1	Reed switch	219097	15898	765972	REF		
	F4-O1	Coil, reed switch	269019	71707	U-6-P	REF		
Q1	D4-P2	Tstr, MOS-FET, P-channel	272146	17856	M104	1	2	
Q2	E5-P2	Tstr, silicon, PNP	225599	07263	S22650	2	2	
Q3	E5-O5	Tstr, silicon, PNP	225599	97263	S22650	REF		
Q4	I2-O3	Tstr, FET, N-channel	288324	15818	U1994E	1	1	
Q6	J3-O2	Tstr, silicon, PNP	281758	01295	SKA5153	2	2	
Q7	J3-N5	Tstr, silicon, PNP	281758	01295	SKA5133	REF		
Q8	I1-N1	Tstr, silicon, PNP	195974	04713	2N3906	3	3	
Q9	I1-M4	Tstr, silicon, PNP	195974	04713	2N3906	REF		
Q10	I1-N2	Tstr, silicon, PNP	195974	04713	2N3906	REF		
R1	D5-O2	Res, comp, 100k $\pm 10\%$, 2w	158659	01121	HB1041	2	2	
R2	D2-O4	Res, comp, 100k $\pm 10\%$, 2w	158659	01121	HB1041	REF		
R3	C5-P1	Res, comp, 220k $\pm 5\%$, $\frac{1}{4}w$	160937	01121	CB2245	1		
R4	D2-P2	Res, met flm, 100k $\pm 1\%$, $\frac{1}{8}w$	248807	91637	Type MFF1/8	3	3	
R5	D1-P1	Res, comp, 180k $\pm 5\%$, $\frac{1}{4}w$	193441	01121	CB1845	1		
R6	D1-O5	Res, comp, 120k $\pm 5\%$, $\frac{1}{4}w$	193458	01121	CB1245	1		
R7	E3-P3	Res, comp, 1M $\pm 5\%$, $\frac{1}{4}w$	182204	01121	CB1055	4		
R8	F3-P2	Res, comp, 22k $\pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	3		
R9	F2-P2	Res, comp, 22k $\pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	REF		

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R10	F1-P2	Res, comp, 1M $\pm 5\%$, $\frac{1}{4}w$	182204	01121	CB1055	REF		
R11	G3-P1	Res, comp, 1M $\pm 5\%$, $\frac{1}{4}w$	182204	01121	CB1055	REF		
R12	D2-O3	Res, met flm, 909k $\pm 1\%$, $\frac{1}{2}w$	159483	91637	Type MFF $\frac{1}{2}$	1	1	
R13	F3-P2	Res, comp, 2.2M $\pm 5\%$, $\frac{1}{4}w$	198390	01121	CB2255	1		
R14	G4-P1	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	7		
R15	I4-O4	Res, met flm, 49.9k $\pm 1\%$, $\frac{1}{8}w$	268821	91637	Type MFF $\frac{1}{8}$	2	2	
R16	I4-P1	Res, met flm, 49.9k $\pm 1\%$, $\frac{1}{8}w$	268821	91637	Type MFF $\frac{1}{8}$	REF		
R17	J1-O4	Res, met flm, 100k $\pm 1\%$, $\frac{1}{8}w$	248807	91637	Type MFF $\frac{1}{8}$	REF		
R18	I2-P1	Res, comp, 100M $\pm 10\%$, $\frac{1}{2}w$	190520	01121	EB1071	1	1	
R19	I2-O5	Res, comp, factory selected (Replace with exact value)						
R20	E1-O5	Res, met flm, 100k $\pm 1\%$, $\frac{1}{8}w$	248807	91637	Type MFF $\frac{1}{8}$	REF		
R21	E3-O5	Res, comp, 1M $\pm 5\%$, $\frac{1}{4}w$	182204	01121	CB1055	REF		
R22	D2-N5	Res, comp, 15k $\pm 5\%$, $\frac{1}{4}w$	148114	01121	CB1535	2		
R23	D4-O2	Res, comp, 15k $\pm 5\%$, $\frac{1}{4}w$	148114	01121	CB1535	REF		
R24	D4-N5	Res, comp, 1.2k $\pm 5\%$, $\frac{1}{4}w$	190371	01121	CB1225	2		
R25	D3-N5	Res, comp, 1.2k $\pm 5\%$, $\frac{1}{4}w$	190371	01121	CB1225	REF		
R26	B1-O5	Res, var, comp, 100 Ω $\pm 30\%$, $\frac{1}{4}w$	281634	71450	Type 201	2	2	
R27	A4-O3	Res, ww, 97.835k, matched					1	
R28	G3-N1	Res, var, ww, 50 Ω $\pm 20\%$, $1\frac{1}{4}w$	112490	71450	Type 110	1	1	
R29	E4-O4	Res, ww, 9.9975k, matched						
R30	E4-O2	Res, ww, 90k, matched						
R31	F4-O5	Res, ww, 899.73k, matched						
R32	G3-O4	Res, var, ww, 500 Ω $\pm 10\%$, $1\frac{1}{4}w$	112433	71450	Type 110	1	1	
R33	I5-O1	Res, met flm, 715k $\pm 1\%$, $\frac{1}{8}w$	236836	91637	Type MFF $\frac{1}{8}$	2	2	
R34	I4-O1	Res, comp, 20k $\pm 5\%$, $\frac{1}{4}w$	221614	01121	CB2035	1		
R35	I3-O1	Res, comp 39k $\pm 5\%$, $\frac{1}{4}w$	188466	01121	CB3935	2		
R36	I4-O1	Res, met flm, 715k $\pm 1\%$, $\frac{1}{8}w$	236836	91637	Type MFF $\frac{1}{8}$	REF		
R37	I2-O1	Res, comp, 39k $\pm 5\%$, $\frac{1}{4}w$	188466	01121	CB3925	REF		
R38	K4-N2	Res, met flm, 97.6 Ω $\pm 1\%$, $\frac{1}{8}w$	151092	91637	Type MFF $\frac{1}{8}$	1	1	

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R39	E4-M4	Res, film, 6.99M $\pm 0.1\%$, 2w	284968	75042	Type MEH	1	1	
R40	H1-N1	Res, var, comp, 25k $\pm 30\%$, $\frac{1}{4}w$	281659	71450	Type 201	1	1	
R41	F4-N2	Res, ww, 777.15k $\pm 0.05\%$, $\frac{3}{4}w$	277913	89536	277913	1	1	
R42	H1-O2	Res, var, comp, 1k $\pm 30\%$, $\frac{1}{4}w$	281642	71450	Type 201	1	1	
R43	F4-M5	Res, ww, 70.555k $\pm 0.05\%$, $\frac{1}{2}w$	277905	89536	277905	1	1	
R44	H2-N4	Res, var, comp, 100 Ω $\pm 30\%$, $\frac{1}{4}w$	281634	71450	Type 201	REF		
R45	F4-O3	Res, car flm, 330k $\pm 1\%$, $\frac{1}{2}w$	107359	75042	Type DCC	1	1	
R46	H2-O5	Res, var, comp, 100k $\pm 30\%$, $\frac{1}{4}w$	281675	71450	Type 201	1	1	
R47	G4-N5	Res, ww, 7.0323k $\pm 0.05\%$, $\frac{1}{2}w$	277889	89536	277889	1	1	
R48	I3-M5	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R49	J3-M5	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R50	I4-M5	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R51	I2-M5	Res, comp, 390 Ω $\pm 5\%$, $\frac{1}{4}w$	147975	01121	CB3915	1		
R52	J3-M5	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R53	I4-M5	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R54	I2-N3	Res, comp, 3.9k $\pm 5\%$, $\frac{1}{4}w$	148064	01121	CB3925	REF		
R55	I5-M5	Res, comp, 22k $\pm 5\%$, $\frac{1}{4}w$	148130	01121	CB2235	REF		
R58	F4-O4	Res, met flm, 243k $\pm 1\%$, 1/8w	235242	91637	Type MFF1/8	1	1	
R59	E5-O2	Res, comp, 4.7 Ω $\pm 5\%$, $\frac{1}{4}w$	193359	01121	CB47G5	1		
R60	A5-P2	Res, comp, 22 Ω $\pm 5\%$, $\frac{1}{4}w$	147884	01121	CB2205	1		
R61	F4-N1	Res, comp, 240 Ω $\pm 5\%$, $\frac{1}{4}w$	221895	01121	CB2415	1		
R62	B3-P3	Res, comp, 1k $\pm 5\%$, 1/4w	148023	01121	CB1025	1		1



R27, R29, R30 and R31 are a factory matched set. For replacement, order Millivolt/Ohms Converter Resistor Set, part number 278291.

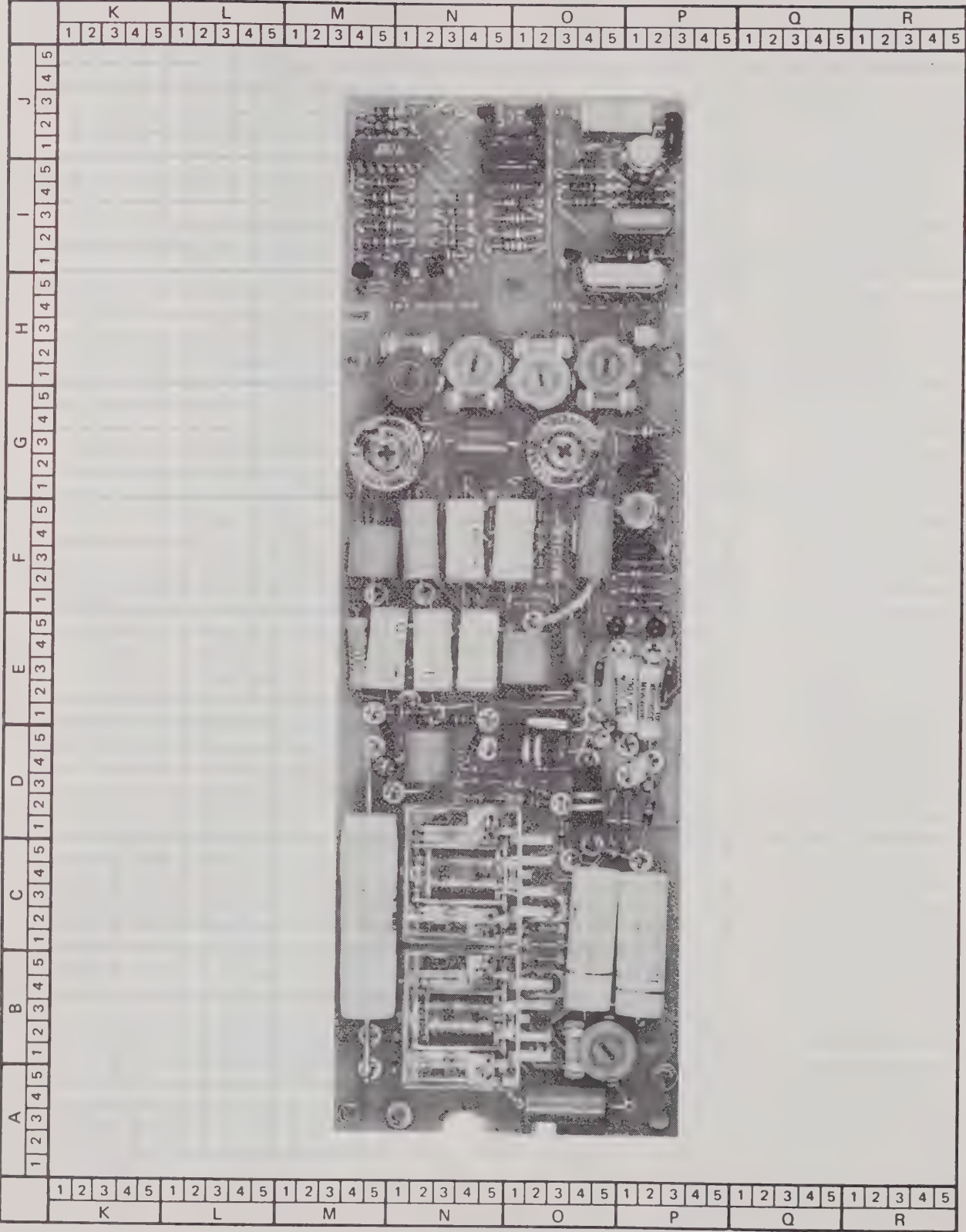


Figure 5-4. MILLIVOLT/OHMS CONVERTER PCB ASSEMBLY

Section 6

Option & Accessory Information

6-1. INTRODUCTION

6-2. This section of the manual contains information pertaining to the accessories and options available for your instrument.

6-3. ACCESSORY INFORMATION

6-4. The accessory information, if applicable, will contain details concerning accessories that may be used with this particular instrument.

6-5. OPTION INFORMATION

6-6. Each of the options available for this instrument, if any, are described separately under headings containing the option number. The option descriptions contain applicable operating and maintenance instructions and field installation procedures. A complete list of replaceable parts for each option is contained at the end of that option description.

ACCESSORY INFORMATION

MODEL 80F-5 VOLTAGE DIVIDER

6-1. INTRODUCTION

6-2. The Accessory Model 80F-5 Voltage Divider allows measurement of up to 5k volts dc to be made using FLUKE 800, 900, and 8000 series voltmeters. Division ratio of this accessory is 1000:1. Accuracy and stability of

the division ratio is ensured using special metal film resistors having matched temperature coefficients.

6-3. Physical design of the Model 80F-5 allows direct mating to the input terminals of the FLUKE voltmeters. A high voltage probe facilitates connection to the measure-

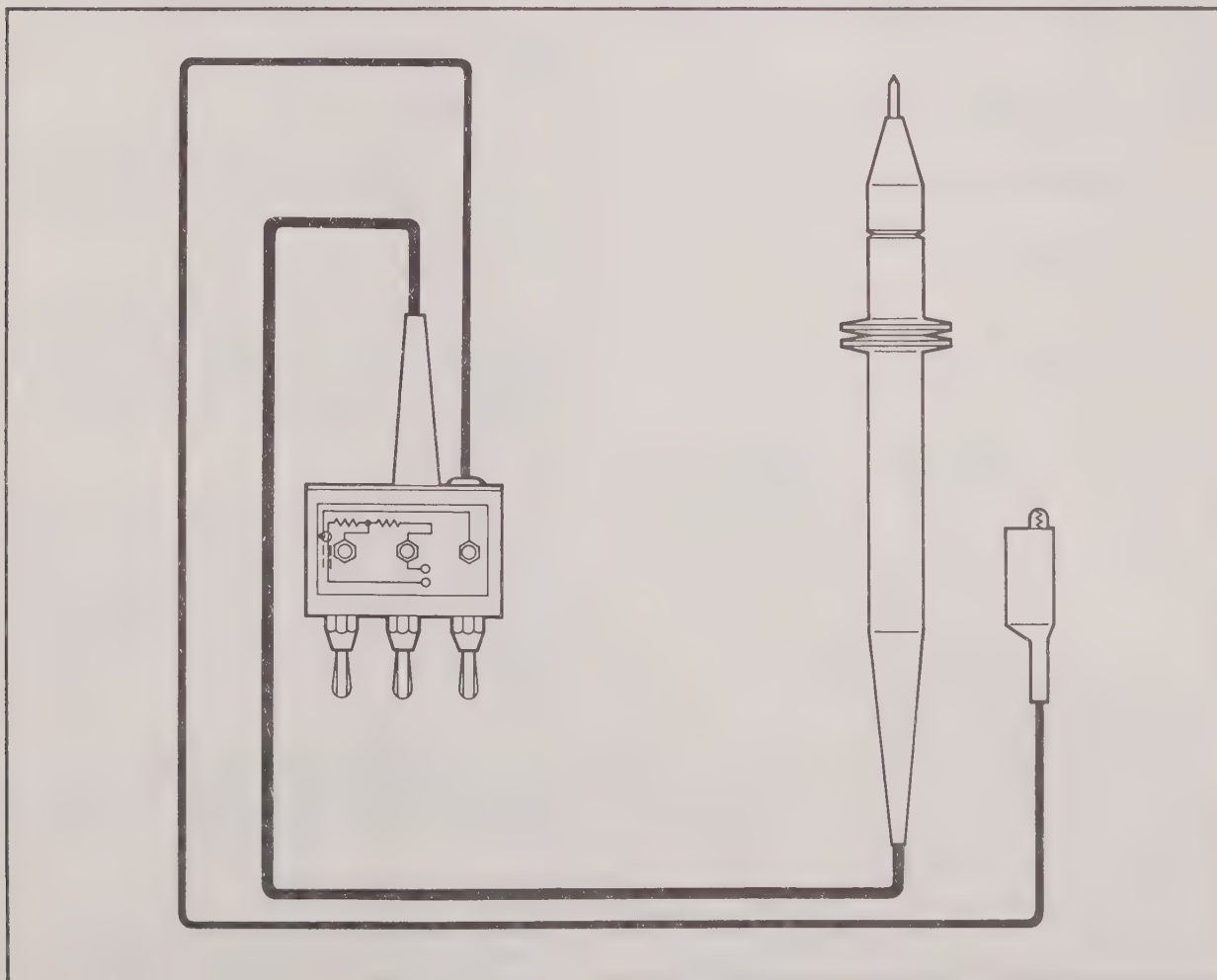


Figure 6-1. MODEL 80F-5 VOLTAGE DIVIDER

ment source. Maintenance is minimized by encapsulation of the divider components.

6-4. Three versions of the Model 80F-5 are available. The basic Model 80F-5 is used with voltmeters having a 10 megohm input resistance. An (01) Option is provided for voltmeters having an 11 megohm input resistance, and an (02) Option is provided for voltmeters having an infinite input resistance (10^3 megohms or greater) at null.

6-5. SPECIFICATIONS

6-6. Electrical

DIVISION RATIO:

1000:1

RATIO ACCURACY:

$\pm 0.01\%$ of input from 500 to 5000 vdc.

RATIO ACCURACY STABILITY:

$\pm 0.01\%$ per month

$\pm 0.05\%$ per year

} Calibrated by internal adjustment

VOLTAGE COEFFICIENT:

Less than 20 ppm total from 0 to 5000 vdc.

TEMPERATURE COEFFICIENT:

0.001%/°C

INPUT RESISTANCE:

50 Megohms

MAXIMUM INPUT VOLTAGE:

5000 vdc

REQUIRED VOLTMETER INPUT RESISTANCE:

80F-5	80F-5 (01)	80F-5 (02)
10 Megohms	11 Megohms	Infinite at null (10^3 megohms or greater)

MAXIMUM OUTPUT VOLTAGE:

5 vdc

6-7. Environmental

OPERATING:

Temperature Range — 0°C to 50°C

Humidity — 0 to 80%

Altitude Range — 0 to 10,000 feet

NON-OPERATING:

Altitude Range — 0 to 50,000 feet

6-8. Mechanical

DIMENSIONS

2.28 inches high x 1.52 inches wide x 1.525 inches deep.

WEIGHT:

20 ounces (340 grams)

6-9. OPERATING INSTRUCTIONS

- Connect the Model 80F-5 output terminals directly to the INPUT terminals of the FLUKE voltmeter.
- Select the appropriate dc voltage range on the FLUKE voltmeter.
- Deenergize the high voltage source to be measured.
- Connect the ground clip (–) and probe (+) to respective low and high sections of the high voltage source.

WARNING!

Lethal voltages will be present between the ground clip and probe of the 80F-5 when the high voltage source is energized.

- Energize the high voltage source. Multiply the FLUKE voltmeter indication by 1000 to obtain the magnitude of the high voltage.

6-10. MAINTENANCE

6-11. General

6-12. The Model 80F-5 requires a minimum amount of maintenance. All that is required is occasional cleaning and calibration.

6-13. Cleaning

6-14. Accumulation of dust or dirt particles between the output terminals of the Model 80F-5 can be removed using clean dry pressurized air. Stubborn particles can be removed following an application of isopropyl alcohol.

6-15. Calibration

6-16. The Model 80F-5 division ratio should be checked every month or every year depending on the accuracy requirement. Ratio accuracy stability is specified at $\pm 0.01\%$ per month and $\pm 0.05\%$ per year. Calibration should be accomplished only after the Model 80F-5 has been in non-operating state for at least four hours at a temperature of 23°C.

6-17. Test equipment requirements are a stable 1000 volt dc source such as the FLUKE Model 332B Voltage Calibrator and the FLUKE voltmeter. To calibrate the Model 80F-5, perform the following steps:

NOTE

The input resistance of the voltmeter must match that of the 80F-5. See paragraph 6-6, REQUIRED VOLTMETER INPUT RESISTANCE.

- Calibrate the FLUKE voltmeter.

- b. Install the Model 80F-5 on the FLUKE voltmeter input terminals.
- c. Unscrew the strain relief on the input cable of the Model 80F-5 and remove the front cover.
- d. Select the appropriate dc voltage range on the FLUKE voltmeter.
- e. Apply 1000 volts dc to the Model 80F-5 high voltage probe.
- f. Adjust the variable resistor on the Model 80F-5 for a 1.0 volt dc indication on the FLUKE voltmeter.
- g. Remove the voltage from the Model 80F-5 high voltage probe.
- h. Install the Model 80F-5 front cover and strain relief.

ACCESSORY INFORMATION

MODEL 80F-15 VOLTAGE DIVIDER

6-1. INTRODUCTION

6-2. The Accessory Model 80F-15 Voltage Divider allows measurement of up to 15k volts dc to be made using FLUKE 800, 900, and 8000 series voltmeters. Division ratio of this accessory is 1000:1. Accuracy and stability of

the division ratio is ensured using special metal film resistors having matched temperature coefficients.

6-3. Physical design of the Model 80F-15 allows direct mating to the input terminals of the FLUKE voltmeters. A high voltage probe facilitates connection to the measurement

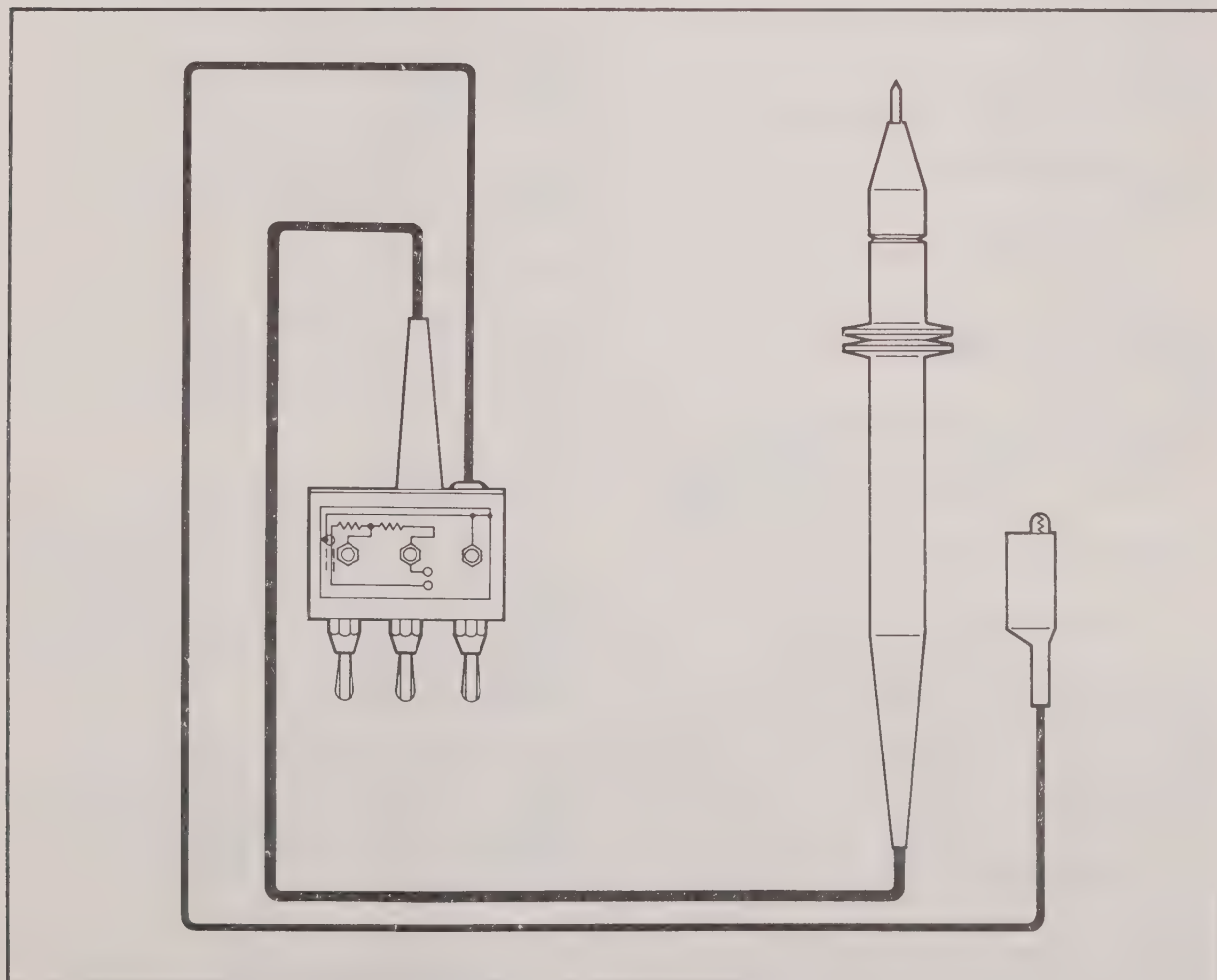


Figure 6-1. MODEL 80F-15 VOLTAGE DIVIDER

source. Maintenance is minimized by encapsulation of the divider components.

6-4. Three versions of the Model 80F-15 are available. The basic Model 80F-15 is used with voltmeters having a 10 megohm input resistance. An (01) Option is provided for voltmeters having an 11 megohm input resistance, and an (02) Option is provided for voltmeters having an infinite input resistance (10^3 megohm or greater) at null.

6-5. SPECIFICATIONS

6-6. Electrical

DIVISION RATIO:

1000:1

RATIO ACCURACY:

±0.01% of input from 1,000 to 15,000 vdc.

RATIO ACCURACY STABILITY:

±0.01% per month }
±0.05% per year } Calibrated by internal adjustment

VOLTAGE COEFFICIENT:

Less than 20 ppm total from 0 to 15,000 vdc.

TEMPERATURE COEFFICIENT:

0.001%/°C

INPUT RESISTANCE:

100 Megohms

MAXIMUM INPUT VOLTAGE:

15,000 vdc

REQUIRED VOLTMETER INPUT RESISTANCE:

80F-15	80F-15 (01)	80F-15 (02)
10 Megohms	11 Megohms	Infinite at null
		(10^3 megohms at greater)

MAXIMUM OUTPUT VOLTAGE:

15 vdc

6-7. Environmental

OPERATING:

Temperature Range – 0°C to 50°C

Humidity – 0 to 80%

Altitude Range – 0 to 10,000 feet

NON-OPERATING:

Altitude Range – 0 to 50,000 feet

6-8. Mechanical

WEIGHT:

24 ounces (680 grams)

DIMENSIONS:

2.725 inches high x 2.69 inches wide x 1.525 inches deep.

6-9. OPERATING INSTRUCTIONS

- a. Connect the Model 80F-15 output terminals directly to the INPUT of the FLUKE voltmeter.
- b. Select the appropriate dc voltage range on the FLUKE voltmeter.
- c. Deenergize the high voltage source to be measured.
- d. Connect the ground clip (–) and probe (+) to respective low and high sections of the high voltage source.

WARNING!

Lethal voltages will be present between the ground clip and probe of the 80F-15 when the high voltage source is energized.

- e. Energize the high voltage source. Multiply the FLUKE voltmeter indication by 1000 to obtain the magnitude of the high voltage.

6-10. MAINTENANCE

6-11. General

6-12. The Model 80F-15 requires a minimum amount of maintenance. All that is required is occassional cleaning and calibration.

6-13. Cleaning

6-14. Accumulation of dust or dirt particles between the output terminals of the Model 80F-15 can be removed using clean dry pressurized air. Stubborn particles can be removed following an application of isopropyl alcohol.

6-15. Calibration

6-16. The Model 80F-15 division ratio should be checked every month or every year depending on the accuracy requirement. Ratio accuracy stability is specified at ±0.01% per month and ±0.05% per year. Calibration should be accomplished only after the Model 80F-15 has been in the non-operating state for at least four hours at a temperature of 23°C.

6-17. Test equipment requirements are a stable 1000 volt dc source such as the FLUKE Model 332B Voltage Calibrator and the FLUKE voltmeter. To calibrate the Model 80F-15, perform the following steps:

NOTE

The input resistance of the voltmeter must match that of the 80F-15. See paragraph 6-6, REQUIRED VOLTMETER INPUT RESISTANCE.

- a. Calibrate the FLUKE voltmeter.
- b. Install the Model 80F-15 on the FLUKE voltmeter input terminals.
- c. Unscrew the strain relief on the input cable of the Model 80F-15 and remove the front cover.
- d. Select the appropriate dc voltage range on the FLUKE voltmeter.
- e. Apply 1000 volts dc to the Model 80F-15 high voltage probe.
- f. Adjust the variable resistor on the Model 80F-15 for a 1.0 volt dc indication on the FLUKE voltmeter.
- g. Remove the voltage from the Model 80F-15 high voltage probe.
- h. Install the Model 80F-15 front cover and strain relief.

ACCESSORY INFORMATION

MODEL 80-RF HIGH FREQUENCY PROBE

6-1. INTRODUCTION

62. The Model 80-RF High Frequency Probe allows measurements over a frequency range of 100 kHz to 500 MHz from 0.25 to 30 volts when using FLUKE voltmeters having an input impedance of 10 megohms $\pm 10\%$. The accuracy of measurement is $\pm 5\%$ from 100 kHz to 100 MHz and $+7\%$ to 500 MHz. The probe operates into any dc voltmeter having an input impedance of 10 megohms $\pm 10\%$. A shielded dual-banana plug on the probe permits direct connection to the voltmeter input.

6-3. SPECIFICATIONS

6-4. Electrical

VOLTAGE	0.25V to 30V
RESPONSE:	Responds to peak value of input. Calibrated to read rms value of a sine wave input.

AC TO DC TRANSFER ACCURACY:
Loaded with 10 megohms $\pm 10\%$.

	100 KHz – 100 MHz	100 MHz – 500 MHz
+10°C to +30°C	$\pm 5\%$	$\pm 7\%$
–10°C to +40°C	$\pm 7\%$	$\pm 15\%$

≤ 3 db at 10 kHz and 700 MHz.

INPUT IMPEDANCE:	4 megohms shunted by 2 ± 0.5 pf.
MAXIMUM INPUT:	30 volts rms AC, 200 volts DC.

6-5. General

CABLE CONNECTIONS:	Shielded dual banana plug Fits all standard 3/4-inch dual banana connectors.
CABLE LENGTH:	4 ft(121.9 cm) minimum.
WEIGHT:	3-½ oz. net.
ACCESSORIES SUPPLIED	Ground Lead Straight Tip Hook Tip High Frequency Adapter

6-6. OPERATING INSTRUCTIONS

6-7. Connect the shielded dual banana plug directly to the voltmeter input terminals, GND to COMMON or LO. Affix the appropriate probe tip to the probe body, then connect the probe to the high frequency circuit under test. When using the Straight or Hook Tip the ground clip must be connected to the test circuit. When using the high frequency adaptor with appropriate 50 ohm connectors, the ground clip is not required.

6-8. The Straight Tip or Hook Tip supplied with the probe can be used for measurements up to 100 MHz. For measurements above 100 MHz the High Frequency Adapter allows connections to 50 ohm terminations. Ensure that the probe is used in conjunction with dc voltmeters having 10 M Ω $\pm 10\%$ input impedance to meet its specifications.

6-9. The maximum input to the probe is 30 volts rms ac, or 200 volts dc. These factors may be used in combination so that an ac signal may be measured riding on a dc voltage of up to 200 volts. However, it must be noted that if ac superimposed on dc is being measured, the dc level must not be changed by more than 200 volts or the resultant transient is apt to damage the diodes inside the probe.

6-10. THEORY OF OPERATION

6-11. Figure 6-1 contains a schematic diagram of the probe. C1 is a dc blocking capacitor, CR1 is used as a detector, and R1, R3, CR2, R2, and Rin form a divider network. C1, charging through CR1 during the negative half cycle of the input produces a positive dc voltage at the CR1-R1 junction which equals the negative peak value of the input signal. The divider network reduces this to the rms value of the input. It can be seen that the probe must be operated into a 10 M Ω load in order to maintain the proper division ratio.

6-12. CR2 provides compensation for the non-linearity of the detector. R3 is a selected part having a value of 50 k Ω to 100 k Ω , as required for proper divider action.

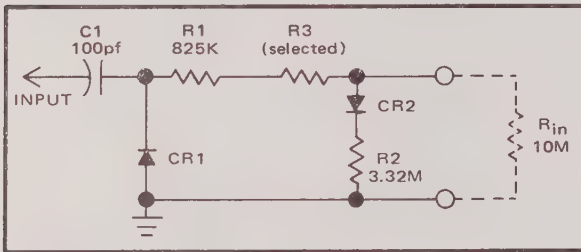


Figure 6-1. SCHEMATIC

6-13. MAINTENANCE

6-14. Performance Checks

6-15. The following checks verify the probe AC to DC Transfer accuracy.

6-16. **LOW FREQUENCY RESPONSE.** Connect equipment as shown in Figure 6-2, and perform the following steps.

- With equipment as shown in connection "A" adjust the ac signal source for an output of 3.000 volts rms at 100 kHz as measured on the DVM.
- In connection "B" with the DVM set to measure dc, observe a probe output of 3.15 to 2.85 volts.
- Placing cables back in connection "A", decrease the ac signal source by 10db (0.95 volts).
- Moving back to connection "B", observe a voltmeter indication of between 1.00 and 0.90 volts (10 db down from 3 volts).

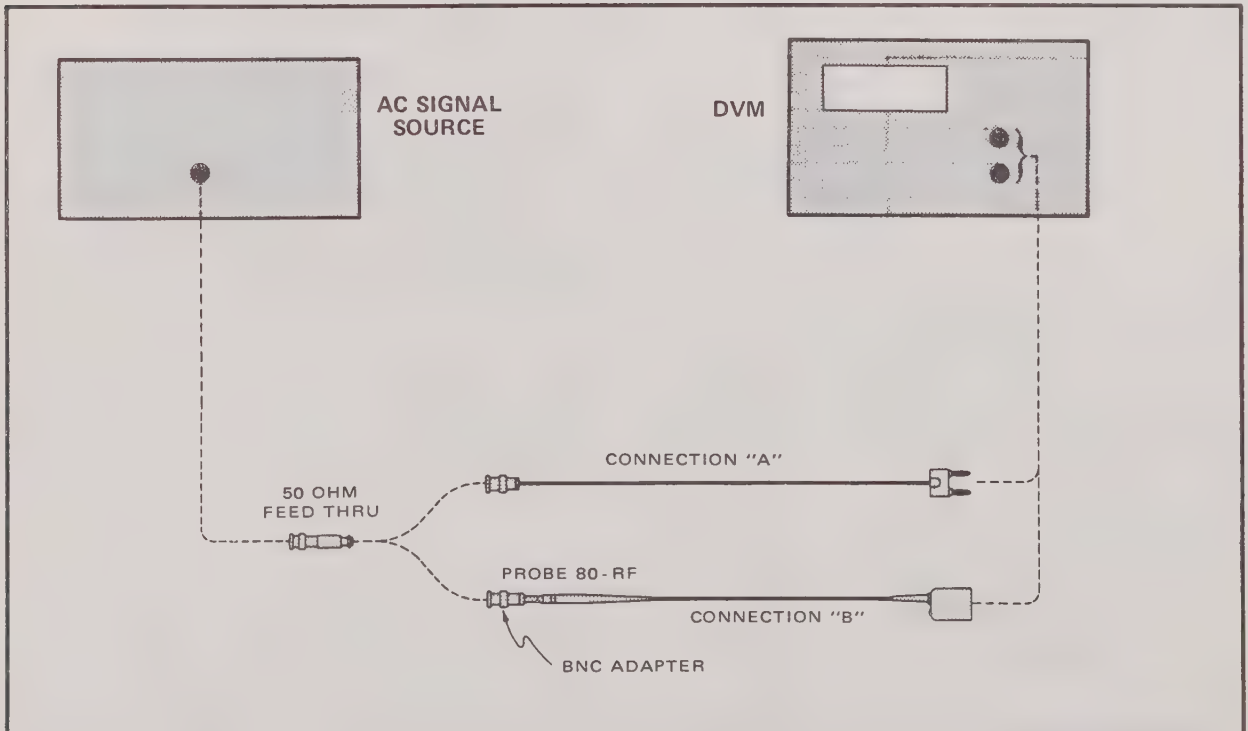


Figure 6-2. LOW FREQUENCY RESPONSE CHECK

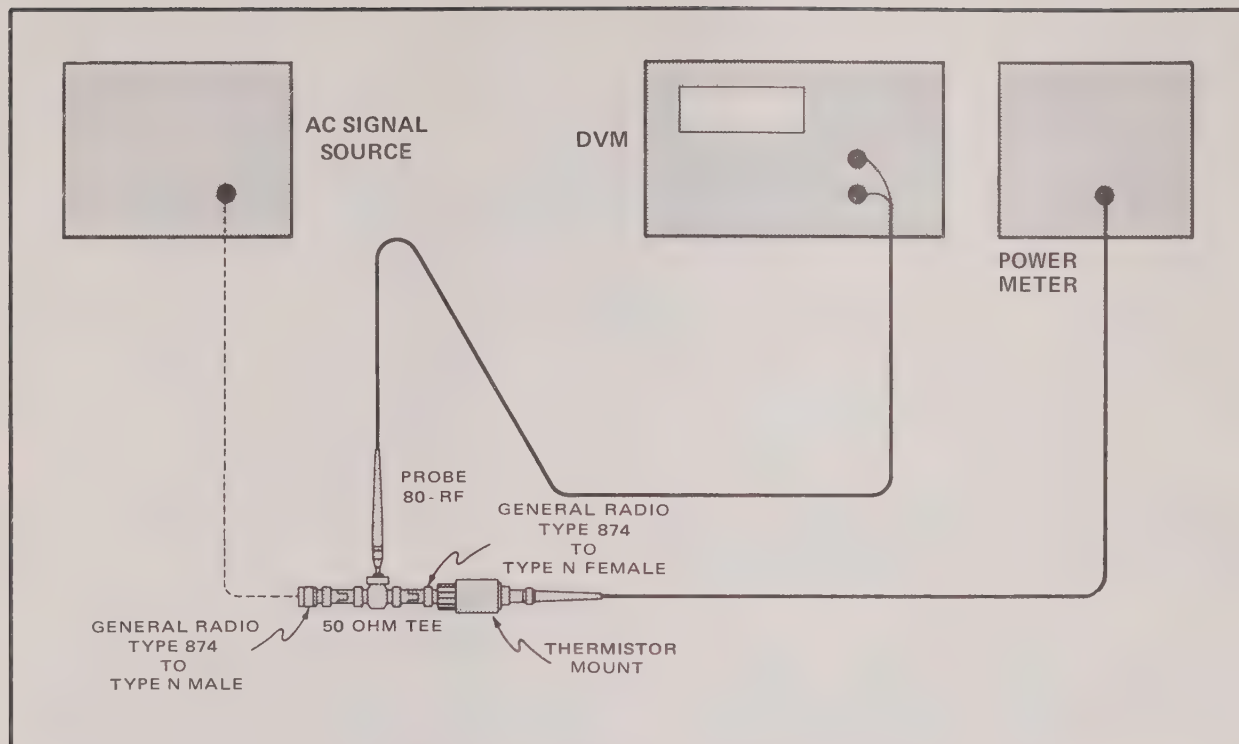


Figure 6-3. HIGH FREQUENCY RESPONSE CHECK

- e. In connection "A", decrease the ac signal source an additional 10 db (to 0.3 volts) as indicated by the voltmeter in its ac function.
- f. Back to "B", observe a voltmeter reading of .315 to .285 vdc.
- g. Return the ac signal source back to 3.000 vrms.
- h. Repeat steps a through g with frequencies of 500 kHz, 1 MHz, and 10 MHz.

6-17. **HIGH FREQUENCY RESPONSE.** Connect equipment to the 80-RF probe as shown in Figure 6-3, and perform the following steps:

- a. Set the ac signal source at 100 MHz with an output level of 10 milliwatts as indicated on the power meter. Ensure that the ac signal source has stabilized at 10 millivolts output.
- b. Observe that the voltmeter indication is between 0.757 and 0.657 volts. (0.707 volts corresponds to 10 milliwatts in 50 ohms).

- c. Repeat the above for frequencies of 200 MHz, 300 MHz, 400 MHz, and 480 MHz.

6-18. Calibration

6-19. Should the 80-RF require recalibration, perform the following steps:

- a. Perform steps a and b in paragraph 6-16, with a frequency of 1 MHz.
- b. Observe the dc voltmeter indication; a reading below 3 volts calls for a decrease in the value of R3, a reading above 3 volts calls for an increase in R3. Resistor R3 should be a 1/8 W metal film type. In a probe that is working properly, a 30 k Ω change in R3 will produce about a 1% reading deviation.

6-20. Cleaning

6-21. The Model 80-RF requires a minimum amount of cleaning. Accumulation of dust or dirt particles between the output terminals of the Model 80-RF can be removed using clean dry pressurized air. Stubborn particles can be removed following an application of isopropyl alcohol.

ACCESSORY INFORMATION

MODEL A90 CURRENT SHUNT

6-1. INTRODUCTION

6-2. The Model A90 Current Shunt is designed for use with any high-impedance ac or dc voltmeter capable of accurately measuring 100 millivolts. Six Fluke precision wire wound and strip resistors provide a 100 millivolt full-scale output for each of six pushbutton current ranges: 0.1, 1, 10, 100, and 1000 milliamperes and 10 amperes

(ac or dc). Basic accuracy is specified over a frequency range of dc to 4 kHz for the 10 ampere range and dc to 10 kHz for the milliampere ranges.

6-3. The instrument is supplied in half-rack case so that it may be conveniently mounted side-by-side with other half-rack instruments in a standard 19-inch rack. A carrying handle detents into custom non-marring feet and serves as a tilt-up bail for bench use.

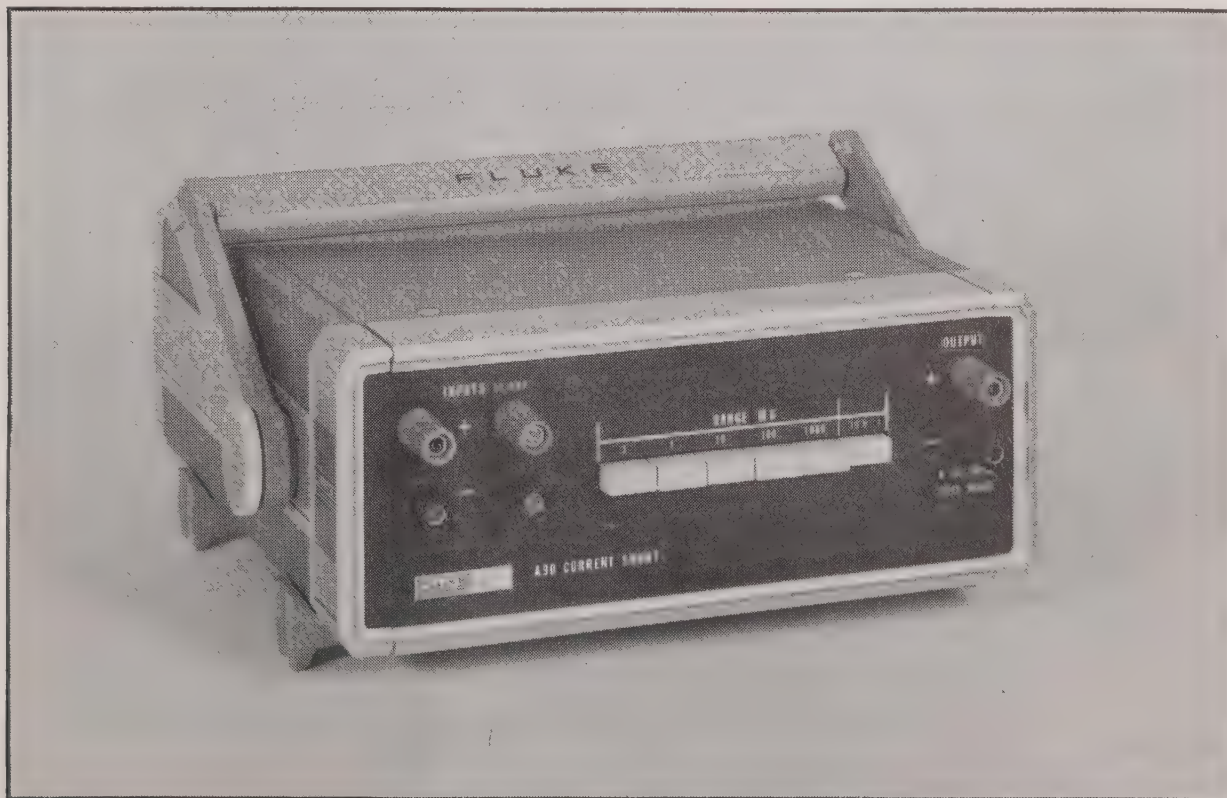
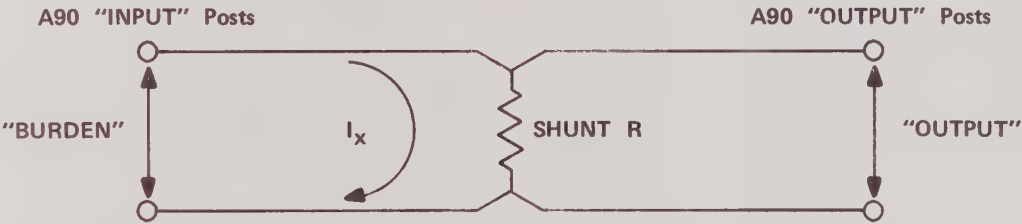


Figure 6-1. MODEL A90 CURRENT SHUNT

Table 6-1. ACCURACY OF A90 (1 year, 15°C - 35°C)

RATED CURRENT RANGE	E BURDEN (APPROX.)	SHUNT R	"OUTPUT" AT RATED CURRENT	"OUTPUT" ACCURACY AS % OF CURRENT INPUT	
				DC ONLY	DC TO 10 KHZ AC
0.1 ma	100 mv	1 kΩ	100 mv	±0.1%	±0.1%
* 0.1 ma	100 mv	1 kΩ	100 mv	+0.0% -0.2%	+0.0% -0.2%
1.0 ma	100 mv	100Ω	100 mv	±0.1%	±0.1%
10 ma	100 mv	10Ω	100 mv	±0.1%	±0.1%
100 ma	102 mv	1Ω	100 mv	±0.1%	±0.1%
1A	120 mv	0.1Ω	100 mv	±0.1%	±0.2%
10A	300 mv	0.01Ω	100 mv	±0.2%	±0.3% (to 4 kHz)

* With 1 MΩ Input R Voltmeter.
When Input R is ≥10 MΩ, use non-asterisked 0.1 ma specification.



Simplified diagram illustrating terms used in table.

6-4. SPECIFICATIONS

6-5. Electrical

RANGE

0.1, 1, 10, 100, and 1000 milliamps and 10 amperes.

ACCURACY

Table 6-1 gives accuracy specifications for the Model A90 only. Total current measurement accuracy is also dependent on the accuracy and input impedance of the voltmeter being used.

SENSITIVITY

100 millivolts full scale.

OVERLOAD

Model A90 will not be damaged by 100% overload on each range below 10 amperes or by 50% overload on the 10 ampere range.

6-6. Mechanical

CURRENT SELECTION

Pushbutton, each range.

CONNECTORS

Positive (+) and negative (–) INPUT and OUTPUT binding posts with separate input posts for 10 ampere range.

DIMENSIONS

The Model A90 outline drawing is shown in Figure 6-2.

RACK MOUNTING KITS (OPTIONAL)

- MEE-7014: Side-by-side Half-rack Mounting Kit
- MEE-7006: Center Rack Mounting Kit
- MEE-7013: Left or right of center Mounting Kit.

6-7. AUXILIARY ELECTRICAL SPECIFICATIONS

6-8. Tables 6-2 through 6-6 provide accuracy specifications for the Model A90 when used with Fluke Models

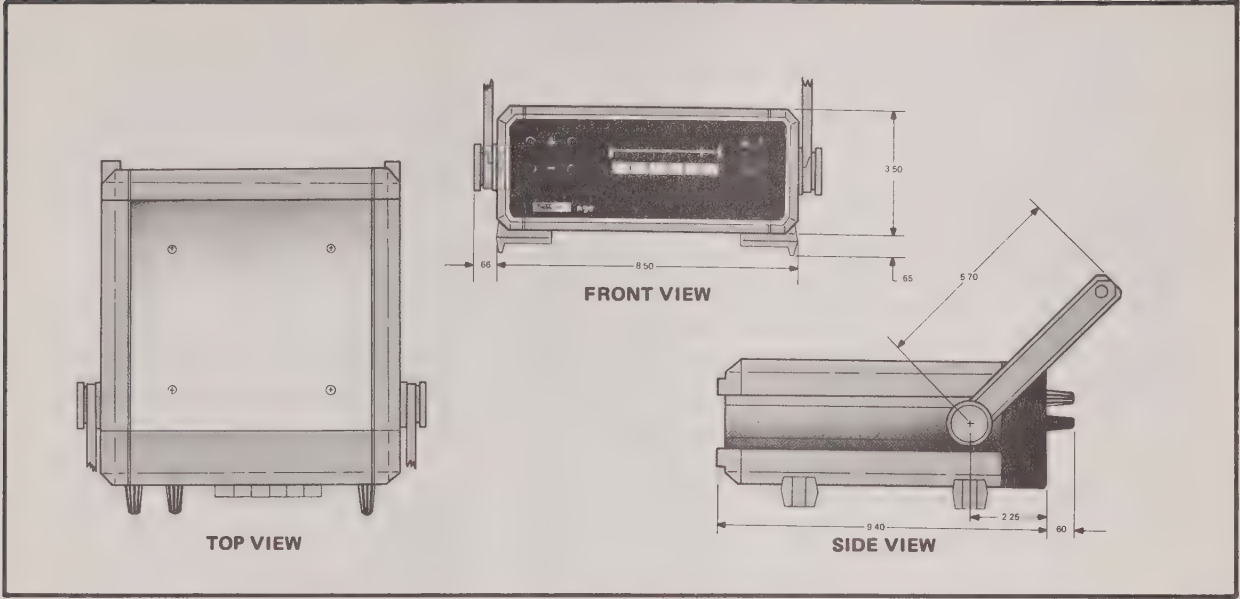


Figure 6-2. MODEL A90 OUTLINE DRAWING

Table 6-2. A90/8100A ACCURACY. 30 days, @ 23°C ±5°C.

DC ACCURACY		
CURRENT RANGE	SPECIFICATION	
0.1 ma	±(0.12% of current input + 0.1 ua)	
1.0 ma	±(0.12% of current input + 1.0 ua)	
10 ma	±(0.12% of current input + 10 ua)	
100 ma	±(0.12% of current input + 0.1 ma)	
1A	±(0.12% of current input + 1.0 ma)	
10A	±(0.22% of current input + 10 ma)	
AC ACCURACY		
CURRENT RANGE	30 Hz – 50 Hz	50 Hz – 10 kHz
0.1 ma	+(0.5% of current input + 1.0 ua) –(0.7% of current input + 1.0 ua)	+(0.2% of current input + 0.5 ua) –(0.4% of current input + 0.5 ua)
1.0 ma	±(0.6% of current input + 10 ua)	±(0.3% of current input + 5.0 ua)
10 ma	±(0.6% of current input + 0.1 ma)	±(0.3% of current input + 50 ua)
100 ma	±(0.6% of current input + 1.0 ma)	±(0.3% of current input + 0.5 ma)
1A	±(0.7% of current input + 10 ma)	±(0.4% of current input + 5.0 ma)
10A	±(0.8% of current input + 100 ma)	±(0.5% of current input + 50 ma)*
* 10A specified to 4 kHz only.		
For:	<u>DC CURRENT</u>	<u>AC CURRENT</u>
	$V_r = 1v$	$V_r = 1v$
	$V_{dfs} = \pm .1000$	$V_{dfs} = .1000$

Table 6-3. A90/8300A ACCURACY

DC CURRENT ACCURACY		
MEASUREMENTS WITHOUT MV/OHMS OPTION INSTALLED		
CURRENT RANGE	24 hr @ 23°C ±1°C	90 days @ 23°C ±5°C
0.1 ma	±(0.1% of current input + 0.1 ua)	±(0.11% of current input + 0.3 ua)
1.0 ma	±(0.1% of current input + 1.0 ua)	±(0.11% of current input + 3.0 ua)
10 ma	±(0.1% of current input + 10 ua)	±(0.11% of current input + 30 ua)
100 ma	±(0.1% of current input + 0.1 ma)	±(0.11% of current input + 0.3 ma)
1A	±(0.1% of current input + 1.0 ma)	±(0.11% of current input + 3.0 ma)
10A	±(0.2% of current input + 10 ma)	±(0.21% of current input + 30 ma)
$V_r = 10 \text{ VDC}$ $V_{dfs} = 0.1000$ (Readout also will display "DC +" or "DC -").		
MEASUREMENTS WITH MV/OHMS OPTION (8300A-02) INSTALLED		
CURRENT RANGE	90 days @ 23°C ±5°C	
0.1 ma	±(0.11% of current input + 0.01 ua)	
1.0 ma	±(0.11% of current input + 0.1 ua)	
10 ma	±(0.11% of current input + 1.0 ua)	
100 ma	±(0.11% of current input + 10 ua)	
1A	±(0.11% of current input + 0.1 ma)	
10A	±(0.21% of current input + 1.0 ma)	
$V_r = 100 \text{ MV (0.1v)}$ $V_{dfs} = 100.000$ (Readout will also display MV DC + or MV DC-)		
AC CURRENT ACCURACY		
MEASUREMENTS WITH AC OPTION 8300A-01 INSTALLED		
90 days @ 23°C ±5°C using AC Zero control periodically.		
CURRENT RANGE	30 Hz – 50 Hz	50 Hz – 10 kHz
0.1 ma	+(0.5% of current input + 0.05 ua) –(0.7% of current input + 0.05 ua)	+(0.1% of current input + 0.05 ua) –(0.3% of current input + 0.05 ua)
1.0 ma	±(0.6% of current input + 0.5 ua)	±(0.2% of current input + 0.5 ua)
10 ma	±(0.6% of current input + 5.0 ua)	±(0.2% of current input + 5.0 ua)
100 ma	±(0.6% of current input + 50 ua)	±(0.2% of current input + 50 ua)
1A	±(0.7% of current input + 0.5 ma)	±(0.3% of current input + 0.5 ma)
10A	±(0.8% of current input + 5.0 ma)	±(0.4% of current input + 5.0 ma)*
$V_r = 1 \text{ VAC}$ $V_{dfs} = .10000$ (Readout will also display "AC") *10A specified to 4 kHz only.		

Table 6-4. A90/9500A SPECIFICATIONS

ACCURACY WHEN UNKNOWN CURRENT IS 20% OR MORE OF A90 CURRENT RANGE. (23°C ±1°C)					
CURRENT RANGE	20 Hz — 50 Hz		50 Hz — 10 kHz		
0.1 ma	+(0.3% of current input + 0.02 ua) −(0.5% of current input + 0.02 ua)		+(0.05% of current input + 0.015 ua) −(0.25% of current input + 0.015 ua)		
1.0 ma	±(0.4% of current input + 0.2 ua)		±(0.15% of current input + 0.15 ua)		
10 ma	±(0.4% of current input + 2.0 ua)		±(0.15% of current input + 1.5 ua)		
100 ma	±(0.4% of current input + 20 ua)		±(0.15% of current input + 15 ua)		
1A	±(0.5% of current input + 0.2 ma)		±(0.25% of current input + 0.15 ma)		
10A	±(0.6% of current input + 2.0 ma)		±(0.35% of current input + 1.5 ma)*		
ACCURACY WHEN UNKNOWN CURRENT IS BETWEEN 10% AND 20% OF A90 CURRENT RANGE.					
A90 INPUT (% OF CURRENT RANGE)	% OF INPUT ABSOLUTE ACCURACY 20 Hz — 50 Hz @ 23°C ±1°C FOR A90 CURRENT RANGE				
	0.1 ma		1 ma — 100 ma	1A	10A
	+	—			
10-11%	0.53%	0.73%	± 0.63%	±0.73%	±0.83%
12-14%	0.50%	0.70%	± 0.60%	±0.70%	±0.80%
15-17%	0.47%	0.67%	± 0.57%	±0.67%	±0.77%
18-20%	0.44%	0.64%	± 0.54%	±0.64%	±0.74%
A90 INPUT (% OF CURRENT RANGE)	% OF INPUT ABSOLUTE ACCURACY 50 Hz — 10 kHz @23°C ±1°C FOR A90 CURRENT RANGE				
	0.1 ma		1 ma — 100 ma	1A	10A*
	+	—			
10-11%	0.23%	0.43%	±0.33%	±0.43%	±0.53%
12-14%	0.20%	0.40%	±0.30%	±0.40%	±0.50%
15-17%	0.17%	0.37%	±0.27%	±0.37%	±0.47%
18-20%	0.13%	0.33%	±0.23%	±0.33%	±0.43%
$V_r = .1v$ $V_{dfs} = .10000$ $TC = 0.005\%$ of current input/°C 20 Hz —50 Hz 0.004% of current input/°C 50 Hz — 10 kHz					
*10A is specified to 4 kHz only.					

8100A, 8300A, 9500A, 891A, 893A, and 931B. Table 6-7 gives V_r and V_{dfs} for each of the voltmeters listed in the tables in addition to various other Fluke voltmeters, where

V_r = Voltage range to be used on the voltmeter
 and V_{dfs} = Nominal voltmeter reading with full-scale current in A90 shunt.

6-9. INSTALLATION

6-10. There are three rack-mount kits available, at additional cost, for use with the Model A90. Kit MEE-7014 allows the Model A90 to be mounted side-by-side with another half-rack instrument in a standard 19-inch rack. Kit MEE-7006 supplies hardware necessary to mount the

Table 6-5. A90/891A AND 893A ACCURACY (Sheet 1 of 2)

WITH 891A AND 893A – DC ACCURACY		
CURRENT RANGE	@ 23°C ±2°C	@ 15°C –35°C
0.1 ma	±(0.11% of current input + 0.02 ua)	±(0.12% of current input + 0.02 ua)
1.0 ma	±(0.11% of current input + 0.2 ua)	±(0.12% of current input + 0.2 ua)
10 ma	±(0.11% of current input + 2.0 ua)	±(0.12% of current input + 2.0 ua)
100 ma	±(0.11% of current input + 20 ua)	±(0.12% of current input + 20 ua)
1A	±(0.11% of current input + 0.2 ma)	±(0.12% of current input + 0.2 ma)
10A	±(0.21% of current input + 2.0 ma)	±(0.22% of current input + 2.0 ma)
$V_r = 1v$ $V_{dfs} = 0.10000$		
WITH 893A – AC ACCURACY @ 23°C ±2°C		
CURRENT RANGE	50 Hz – 10 kHz	
0.1 ma	+(0.05% of current input + 0.025 ua) –(0.25% of current input + 0.025 ua)	
1.0 ma	±(0.15% of current input + 0.25 ua)	
10 ma	±(0.15% of current input + 2.5 ua)	
100 ma	±(0.15% of current input + 25 ua)	
1A	±(0.25% of current input + 0.25 ma)	
10A	±(0.35% of current input + 2.5 ma)*	
WITH 893A – AC ACCURACY @ 15°C –35°C		
CURRENT RANGE	5 Hz – 10 Hz	10 Hz – 20 Hz
0.1 ma	+(1.0% of current input + 0.25 ua) –(1.2% of current input + 0.25 ua)	+(0.5% of current input + 0.1 ua) –(0.7% of current input + 0.1 ua)
1.0 ma	±(1.1% of current input + 2.5 ua)	±(0.6% of current input + 1.0 ua)
10 ma	±(1.1% of current input + 25 ua)	±(0.6% of current input + 10 ua)
100 ma	±(1.1% of current input + 0.25 ua)	+(0.6% of current input + 0.1 ma)
1A	±(1.2% of current input + 2.5 ma)	±(0.7% of current input + 1.0 ma)
10A	±(1.3% of current input + 25 ma)	±(0.8% of current input + 10 ma)
893A – AC ACCURACY @ 15°C –35°C.		
CURRENT RANGE	20 Hz – 50 Hz	50 Hz – 10 kHz
0.1 ma	+(0.15% of current input + 0.025 ua) –(0.35% of current input + 0.025 ua)	+(0.1% of current input + 0.025 ua) –(0.3% of current input + 0.025 ua)
1.0 ma	±(0.25% of current input + 0.25 ua)	±(0.2% of current input + 0.25 ua)
10 ma	±(0.25% of current input + 2.5 ua)	±(0.2% of current input + 2.5 ua)
100 ma	±(0.25% of current input + 25 ua)	±(0.2% of current input + 25 ua)
1A	±(0.35% of current input + 0.25 ma)	±(0.3% of current input + 0.25 ma)
10A	±(0.45% of current input + 2.5 ma)	±(0.4% of current input + 2.5 ma)*

Table 6-5. A90/891A AND 893A ACCURACY (Sheet 2 of 2)

$$V_r = 1\text{v (AC or DC)}$$

$$V_{dfs} = 0.10000$$

* 10A is specified to 4 kHz only.

Table 6-6. A90/931B SPECIFICATIONS

ACCURACY WHEN UNKNOWN CURRENT IS 10% OR MORE OF A90 CURRENT RANGE				
CURRENT RANGE	% OF INPUT ABSOLUTE ACCURACY			SPECIFICATIONS
	2 Hz – 3 Hz	3 Hz – 5 Hz	5 Hz – 30 Hz	30 Hz – 10 kHz
0.1 ma	+1.0% –1.2%	+0.5% –0.7%	+0.2% –0.4%	+(0.05% of current input + 5 na) –(0.25% of current input + 5 na)
1.0 ma	±1.1%	±0.6%	±0.3%	±(0.15% of current input + 50 na)
10 ma	±1.1%	±0.6%	±0.3%	±(0.15% of current input + 0.5 ua)
100 ma	±1.1%	±0.6%	±0.3%	±(0.15% of current input + 5 ua)
1A	±1.2%	±0.7%	±0.4%	±(0.25% of current input + 50 ua)
10A	±1.3%	±0.8%	±0.5%	±(0.35% of current input + 0.5 ma)*
TC=	±0.1%/°C	±0.05%/°C	±0.025%/°C	±0.0025%/°C
$V_r = 100\text{ MV}$ $V_{dfs} = 100.000$				
* 10A is specified to 4 kHz only.				

Table 6-7. “ V_r ” AND “ V_{dfs} ” FOR VOLTMETERS OF TABLES 6-2 THROUGH 6-6

VOLTMETER	“ V_r ”	“ V_{dfs} ”
8300A (Without MV/Ohms)	10v	.010
8100A, 871A, 873A, 881A, 883A, 885A, 887A, 891A, 893A	1v	.100
801, 803, 801B, 803B, 803D, 821A, 823A, 825A	0.5v	.100
9500A, 910A	0.1v	.100
8300A (With MV/Ohms), 931A, 931B	100 MV	100.0
$V_r =$ Voltage range to be used on the voltmeter. $V_{dfs} =$ Nominal voltmeter reading with full-scale current in A90 shunt.		

instrument in the center of the rack. Kit MEE-7013 supplies two different sized rack ears so that the instrument can be mounted to the left or to the right of rack center.

6-11. OPERATING INSTRUCTIONS

6-12. A description of Model A90 controls and terminals is given in Figure 6-3.

6-13. Equipment Connections

6-14. It is recommended that the Model A90 always be used in the “LO” lead as shown in Figure 6-4A. When used in the “HI” lead, as shown in Figure 6-4B, the distributed capacitance, C_{DIST} , loads the source. When connected in the “HI” lead, the voltmeter guard should either be connected as shown or else the voltmeter should be battery operated.

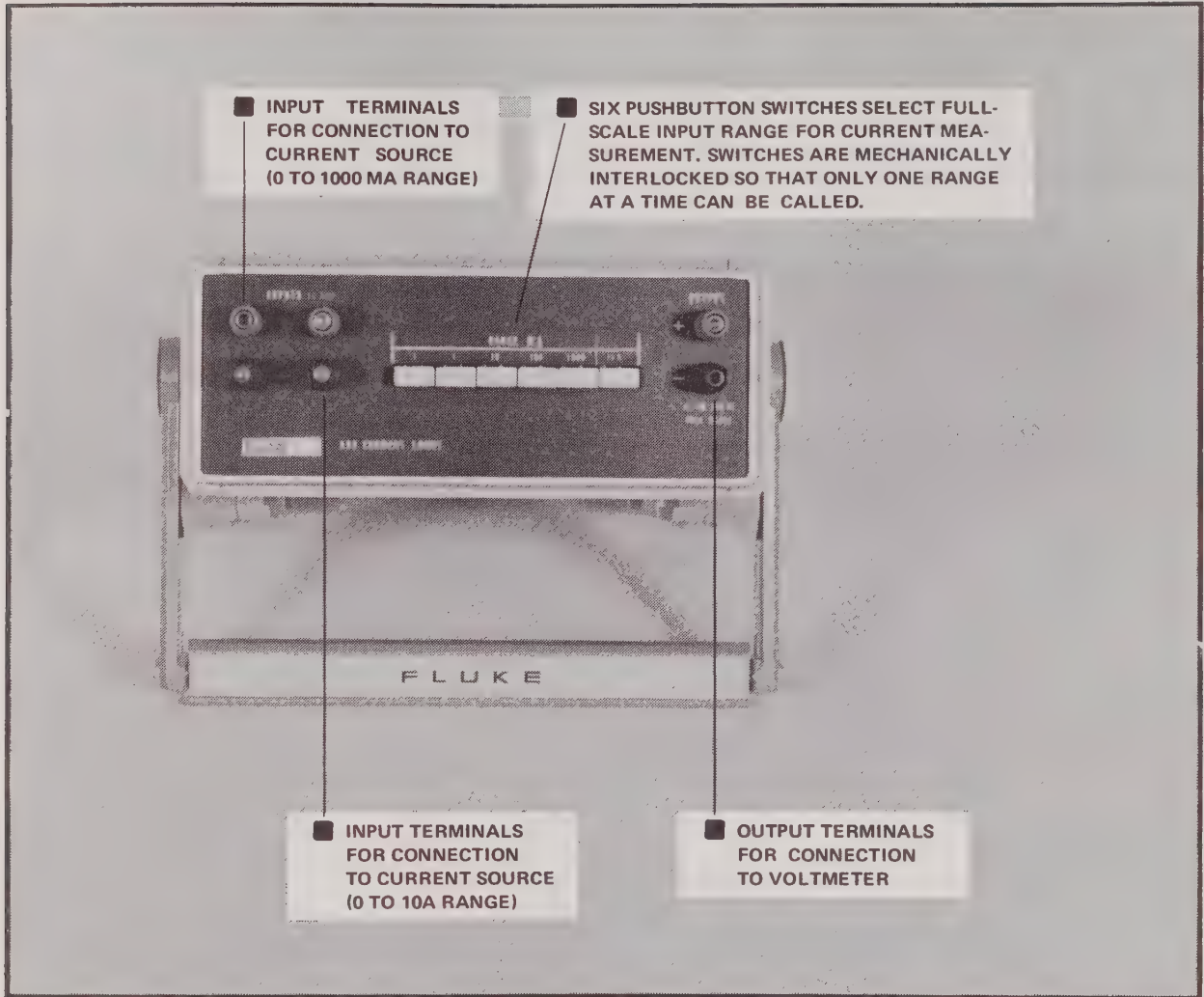


Figure 6-3. MODEL A90 CONTROLS AND TERMINALS.

6-15. At high ac currents, performance of the A90 may depend upon the manner in which the current leads are connected to the input binding posts. Optimum performance is obtained when the input current leads are twisted.

6-16. Voltmeter Impedance

6-17. The input impedance of the voltmeter which is used with the Model A90 is significant with regard to total measurement accuracy. As indicated in the specifications, Model A90 measurement accuracy is derated for voltmeters having finite input impedance. As the voltmeter input capacity increases, the Model A90 response rolls off at the high end; and as the voltmeter input resistance decreases, the response shifts downward, resulting in negative measurement errors.

6-18. Combining Model A90 And Voltmeter Specifications

6-19. Combined specifications for the A90 when used with various Fluke voltmeters is given in Tables 6-2 through 6-6. When the A90 is used with other voltmeters, the following information may be used to combine specifications.

6-20. Equation 1 (Figure 6-5) is used to combine A90 and voltmeter specifications for overall accuracy. The "W" term is taken from Table 6-1, and the "X", "Y" and "Z" terms are taken from voltmeter specifications (data sheets). All Fluke voltmeter specifications, except the Model 910A, contain the "X" term; they usually list the "Y" term and occasionally the "Z" term. Model 910A accuracy speci-

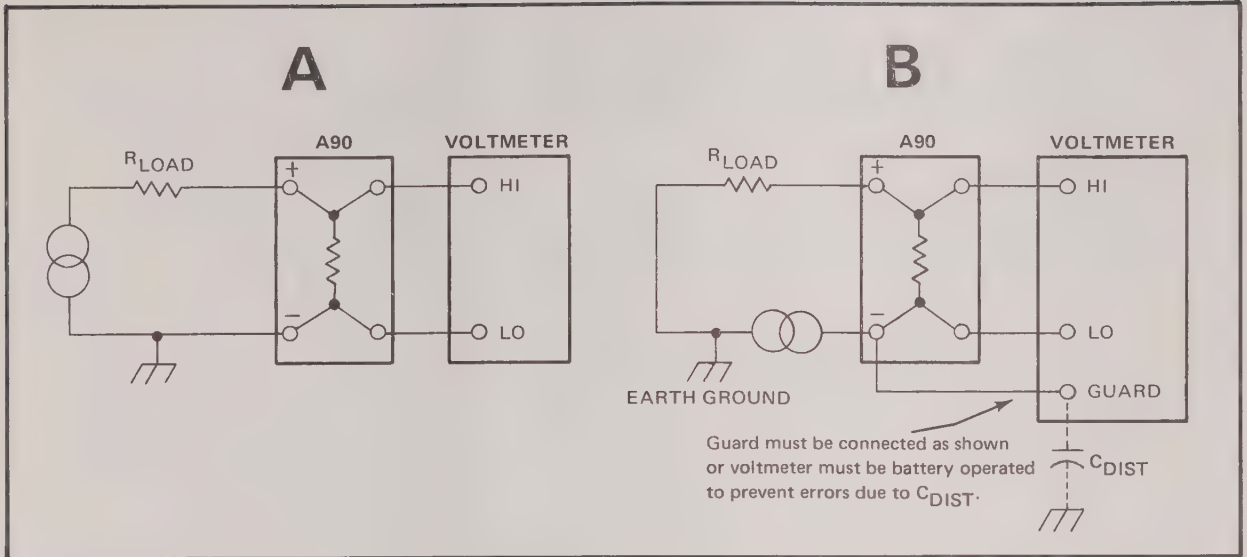


Figure 6-4. EQUIPMENT CONNECTIONS FOR CURRENT MEASUREMENT.

EQUATION 1. COMBINING A-90 SPECIFICATION WITH VOLTMETER SPECIFICATION.A-90 Specification

(from Table 6-1)

Voltmeter Specification

(from Voltmeter Data Sheet)

$$\begin{array}{c}
 \pm \left| \begin{array}{c} W \\ \hline \end{array} \right| \% \\
 \downarrow \\
 = + \left[(W + X) \% \text{ of current input} \right. \\
 \left. + \frac{V_r}{0.1} \times \left(Y + \frac{Z}{10000} \right) \% \text{ of current range} \right]
 \end{array}$$

$\pm \left(\left| \begin{array}{c} X \\ \hline \end{array} \right| \% \text{ of input} \right) + \left| \begin{array}{c} Y \\ \hline \end{array} \right| \% \text{ of range} + \left| \begin{array}{c} Z \\ \hline \end{array} \right| \text{ uv}$
 $V_r = \text{Lowest voltmeter range that will measure 100 MV}$

EXAMPLE 1: Accuracy using 10 ma DC A-90 range with 891A.A-90 Specification

(from Table 6-1)

891A Specification

(from 891A Data Sheet)

$$\begin{array}{c}
 \pm \left| \begin{array}{c} 0.1 \\ \hline \end{array} \right| \% \\
 \downarrow \\
 = \pm \left[(0.1 + 0.01) \% \text{ of current input} \right. \\
 \left. + \frac{1.0}{0.1} \times (0.001 + \frac{10}{10,000}) \% \text{ of current range} \right] \\
 = \pm \left[0.11\% \text{ of current input} + 0.02\% \text{ of current range} \right] \\
 = \pm \left[0.11\% \text{ of current input} + 2 \text{ ua} \right]
 \end{array}$$

$\pm \left(\left| \begin{array}{c} 0.01 \\ \hline \end{array} \right| \% \text{ of input} \right) + \left| \begin{array}{c} 0.001 \\ \hline \end{array} \right| \% \text{ of range} + \left| \begin{array}{c} 10 \\ \hline \end{array} \right| \text{ uv}$
 $V_r = 1.0$
 $(891A's 1v DC Range)$

Figure 6-5. EQUATION 1 – COMBINING A90 AND VOLTMETER SPECIFICATIONS (Sheet 1 of 2)

EXAMPLE 2: Accuracy using 0.1 ma AC A-90 range with 873A at 1 kHz.

Model 873A has 1 megohm input impedance in its AC mode so separate accuracy statements are required for positive and negative limits of error for measurements made on the A-90's 0.1 ma range.

Positive Limit of Error

A-90 Specification

873A Specification

$$\begin{aligned}
 & + \left| 0.0 \right| \% \\
 & \pm \left| 0.2 \right| \% \text{ of input} + \left| 25 \right| \text{ uv} \\
 & \text{"Vr" is 873A's 1v AC Range} \quad \text{No "Y" Term In Spec.} \\
 & = + \left[(0.0 + 0.2) \% \text{ of current input} + \frac{1}{0.1} \times (0 + \frac{25}{10000}) \% \text{ of current range} \right] \\
 & = + \left[0.2\% \text{ of current input} + 0.025\% \text{ of current range} \right]
 \end{aligned}$$

Negative Limit of Error

$$\begin{aligned}
 & = - \left[(0.2 + 0.2) \% \text{ of current input} + 0.025\% \text{ of current range} \right] \\
 & = - \left[0.4\% \text{ of current input} + 0.025\% \text{ of current range.} \right]
 \end{aligned}$$

Figure 6-5. EQUATION 1 – COMBINING A90 AND VOLTMETER SPECIFICATIONS (Sheet 2 of 2)

cation consists of "Y" term only. If "X", "Y", or "Z" do not appear in a voltmeter accuracy specification, it should be treated as a zero in Equation 1. The voltmeter must be used on the lowest range that can measure 100 millivolts. This range is assigned the symbol " V_r " in Equation 1. V_r is always stated as volts, i.e., 100 millivolt range equals 0.1 volts for V_r .

6-21. Equation 2 (Figure 6-6) may be used to convert the voltmeter voltage reading to current.

6-22. THEORY OF OPERATION

6-23. The schematic diagram of the Model A90 is located at the back of the manual. In the milliamperage ranges, current is directed through the appropriate shunt resistor by switches S1A through S5A, and the corresponding output voltage is connected to the output terminals through switches S1 through S5, decks B and C. In 10 ampere range, the input current is applied directly to the shunt resistor, and the output voltage is connected to the output terminals through switch S6.

6-24. All shunt resistors are four-terminal shunts or are connected in a four-terminal switching arrangement so that lead resistance does not affect measurement accuracy.

6-25. MAINTENANCE

6-26. The following paragraphs contain instructions for cleaning and calibrating the Model A90.

6-27. Cleaning

6-28. The instrument should be cleaned periodically to remove dust, grease, and other contamination. The following procedure should be adhered to when cleaning the instrument:

- Remove loose contamination with low-pressure, clean, dry air.
- Clean front panel and exterior surfaces with anhydrous ethyl alcohol or a soft cloth dampened in a mild solution of detergent and water.

CAUTION!

Do not use aromatic hydrocarbons or chlorinated solvents on the front panel, because they will react with the Lexan binding posts.

$$I_x = I_r \times \frac{V_d}{V_{dfs}}$$

Where: I_x = magnitude of unknown current in units of A90 "RANGE" used. (i.e. ma or amps).
 I_r = A90 Rated Current "RANGE".
 V_d = Voltmeter reading.
 V_{dfs} = Nominal Voltmeter reading with rated current flowing in A90. " V_{dfs} " and " V_r " are tabulated in Table 6-7 for each voltmeter listed in Tables 6-2 through 6-6. Note that " V_{dfs} " multiplies or divides " V_d " by powers of 10 so it is simple to manipulate.

EQUATION 2. CONVERTING VOLTAGE READINGS TO CURRENT

Example: An 8100A reads =.0643 when used with an A90 in the 10 ma range. What current is flowing?

I_r = 10 ma (A90 "Rated Current Range")
 V_d = .0643 (Voltmeter reading)
 V_{dfs} = .1000 (From Table 6-7)

Answer: $I_x = 10 \text{ ma} \times \frac{.0643}{.1000} = 6.43 \text{ ma}$

Figure 6-6. Equation 2 – CONVERTING VOLTAGE READINGS TO CURRENT

6-29. Test Equipment

6-30. Test equipment required for calibration and testing of the Model A90 is shown in Table 6-8. If the recommended equipment is not available, other equivalent equipment may be used.

Table 6-8. LIST OF TEST EQUIPMENT

NAME	RECOMMENDED EQUIPMENT
Constant Current Source	Fluke Model 382A
DC Differential Voltmeter	Fluke Model 895A or 885A
Low-Thermal Leads	
4-Terminal Ohmmeter	Fluke Model 8300A with Option -02

6-31. Calibration

6-32. PRELIMINARY CHECKS. Make the resistance checks shown in Table 6-9. Values are approximate since check is intended to show only gross errors, such as defective or open resistors.

6-33. .1 MA AND 1 MA RANGE CHECKS. Connect the ohmmeter and A90, as shown in Figure 6-7, for 4-terminal resistance measurements, and perform the following steps:

- Set the A90 to the .1 MA range. The ohmmeter should indicate between 1.00050 and 0.99950 kilohms. If the measured resistance is not within these limits, the .1 MA shunt, R6, is defective and must be replaced.
- Set the A90 to the 1 MA range. The ohmmeter should indicate between 100.07 and 99.93 ohms. If the measured resistance is not within these limits, the 1 MA shunt, R5, is defective and must be replaced.

6-34. 10 MA, 100 MA, AND 1000 MA RANGE CHECKS. Connect the constant current generator, differential voltmeter, and A90 as shown in Figure 6-8 and perform the following steps:

- Set the A90 to the 10 MA range.
- Set the differential voltmeter controls as follows:

RANGE	1 Volt
NULL Sensitivity	100 μ V
Readout Dials	0.100000

Table 6-9. RESISTANCE CHECKS

OHMMETER CONNECTIONS	MODEL A90	
	RANGE	APPROXIMATE RESISTANCE (OHMS)
INPUT Terminals	.1 MA	1000
	1 MA	100
	10 MA	10
	100 MA	1
	1000 MA	0.1
	10A	∞
INPUT (10A Terminals)	10A	0.01
OUTPUT Terminals	10A	0.01
	1000 MA	0.1
	100 MA	1
	10 MA	10
	1 MA	100
	.1 MA	1000

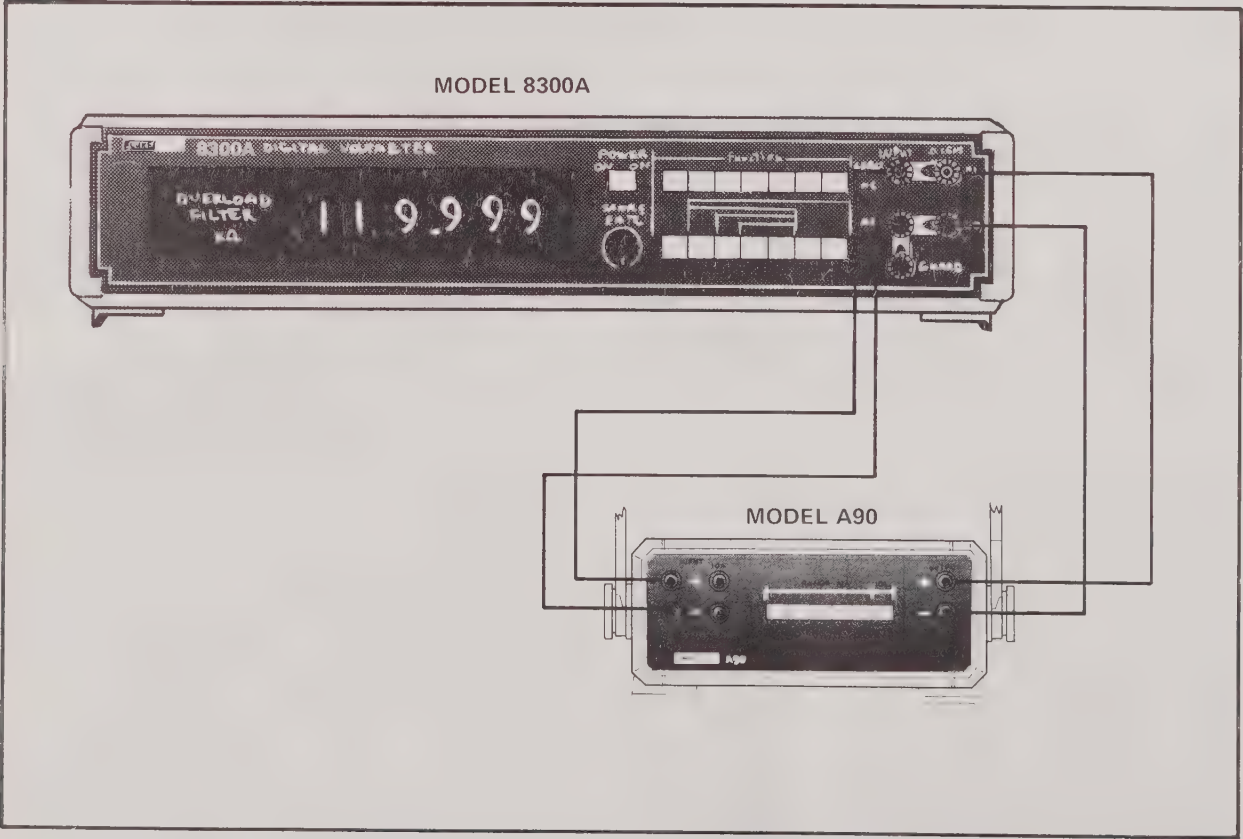


Figure 6-7. EQUIPMENT CONNECTIONS — .1 MA AND 1 MA RANGE CHECKS

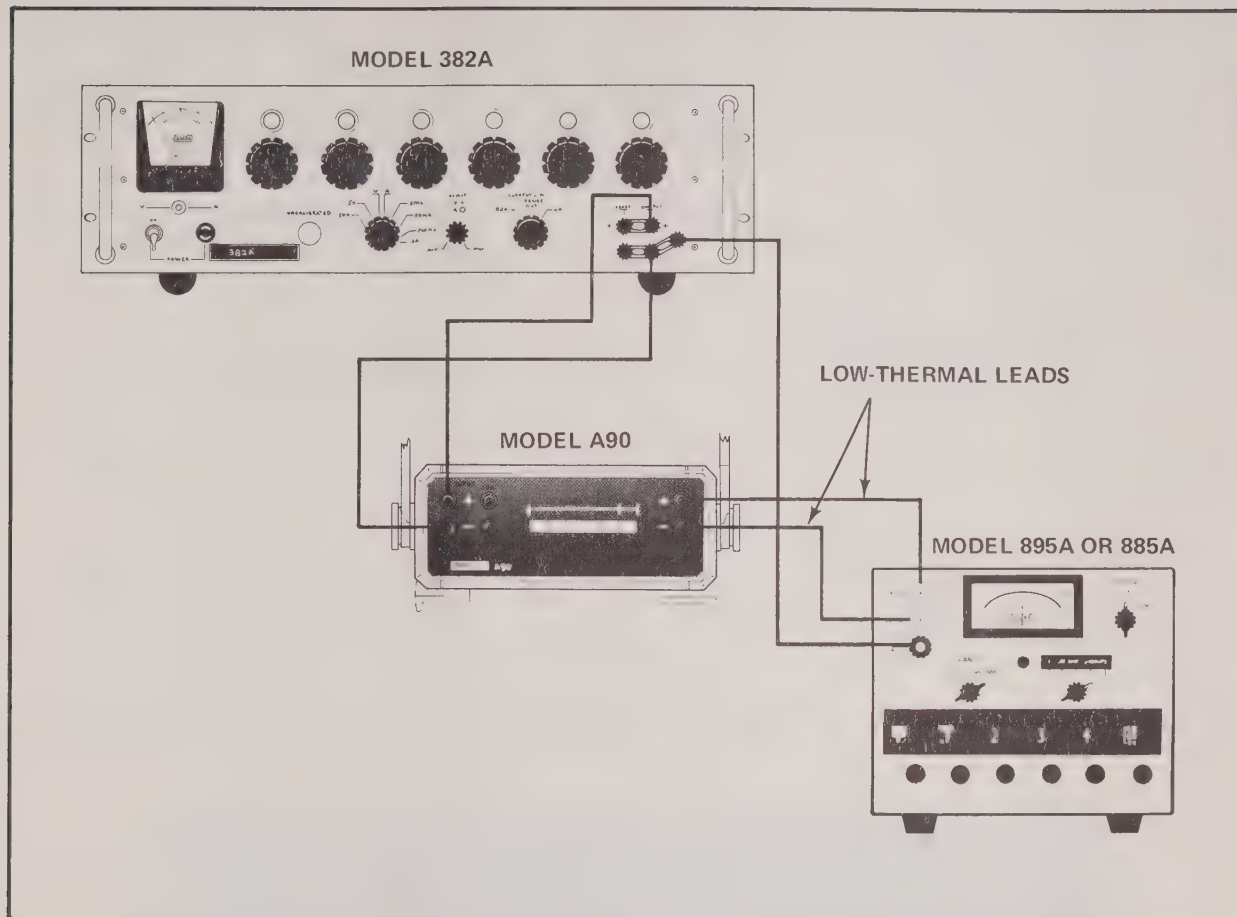


Figure 6-8. EQUIPMENT CONNECTIONS — 10 MA, 100 MA, AND 1000 MA RANGE CHECKS

- c. Set the constant current generator for 10.0000 milliamperes output. The differential voltmeter should indicate null within ± 80 microvolts. If the voltmeter does not indicate within these limits, the 10 MA shunt, R4, is defective and must be replaced.
- d. Change the A90 range to 100 MA and the constant current generator output to 100 milliamperes. The differential voltmeter should indicate null within ± 80 microvolts. If the voltmeter does not indicate within these limits, the 100 MA shunt, R3, is defective and must be replaced.
- e. Change the A90 range to 1000 MA and the constant current generator output to 1000 milliamperes. The differential voltmeter should indicate null within ± 80 microvolts. If the $+80$ microvolt limit is not met, the 1000 MA shunt, R2, should be replaced. If the -80 microvolt limit is

not met, R2 is low in ohmic value and can be trimmed to its desired value by carefully removing a small amount of material from the edge of the shunt using a whetstone.

6-35. 10 AMPERE RANGE CHECK. Connect equipment as shown in Figure 6-8, leaving the constant current generator temporarily disconnected from the A90, and perform the following steps:

- a. Set the differential voltmeter controls as follows:

RANGE	1 Volt
NULL Sensitivity	100 μ V
Readout Dials	0.00000

The voltmeter should indicate less than ± 4 microvolts of thermal offset. If more than ± 4 microvolts of offset is observed, check for cold solder joints or possible thermal generators in the test

- setup. When thermal offset has been reduced to within ± 4 microvolts, proceed to step (b).

b. Connect the constant current generator to the 10 AMP binding posts of the A90 and set the A90 to the 10A range.

c. Set the differential voltmeter controls as follows:

RANGE	1 Volt
NULL Sensitivity	100 μV
Readout Dials	.020000
- d. Set the constant current generator output to 2 amperes. The voltmeter should indicate null within ± 80 microvolts. If the +80 microvolt limit is not met, the 10 ampere shunt, R1, should be replaced. If the -80 microvolt limit is not met, R1 is low in ohmic value and can be trimmed to its desired value by carefully removing a small amount of material from the edge of the shunt using a whetstone.

6-36. LIST OF REPLACEABLE PARTS

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
J1, J2, J5 J3, J4, J6		CURRENT SHUNT – Figure 6-9	A90					
		Shunt PCB Assembly (See Figure 6-9)	A90-403	89536	A90-403	1		
		Binding post, red, +	275552	89536	275552	3		
		Binding post, black –	275560	89536	275560	3		
		Cover, bottom	224360	89536	224360	1		
		Cover, top	224352	89536	224352	1		
		Foot	230037	89536	230337	4		
		Handle, carrying	231423	89536	231423	1		
		Panel, front	A90-208	89536	A90-208	1		
		Panel, rear	A90-209	89536	A90-209	1		

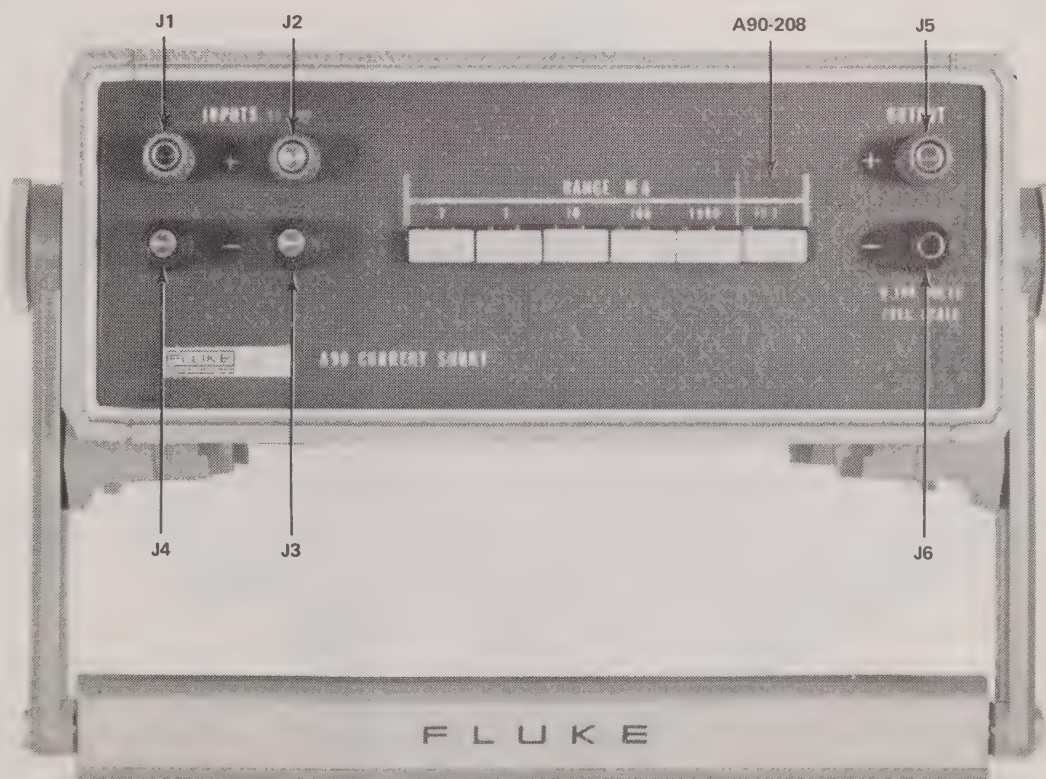


Figure 6-9. MODEL A90 CURRENT SHUNT (Sheet 1 of 2)

REF DESIG	INDEX NO	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
		SHUNT PCB ASSEMBLY – Figure 6-9	A90-403	89536	A90-403	REF		
R1		Res, ww, 0.010Ω ±0.2%, 1w	34-4022	89536	34-4022	1		
R2		Res, ww, 0.10Ω ±0.1%, 1w	224121	89536	224121	1		
R3		Res, ww, 1.0Ω ±0.1%, ½w	224089	89536	224089	1		
R4		Res, ww, 10Ω ±0.1%, ½w	224071	89536	224071	1		
R5		Res, ww, 100Ω ±0.03%, ½w	155846	89536	155846	1		
R6		Res, ww, 1 KΩ ±0.04%, ½w	131706	89536	131706	1		
S1 thru S6		Switch assembly, RANGE MA	A90-802	89536	A90-802	1		

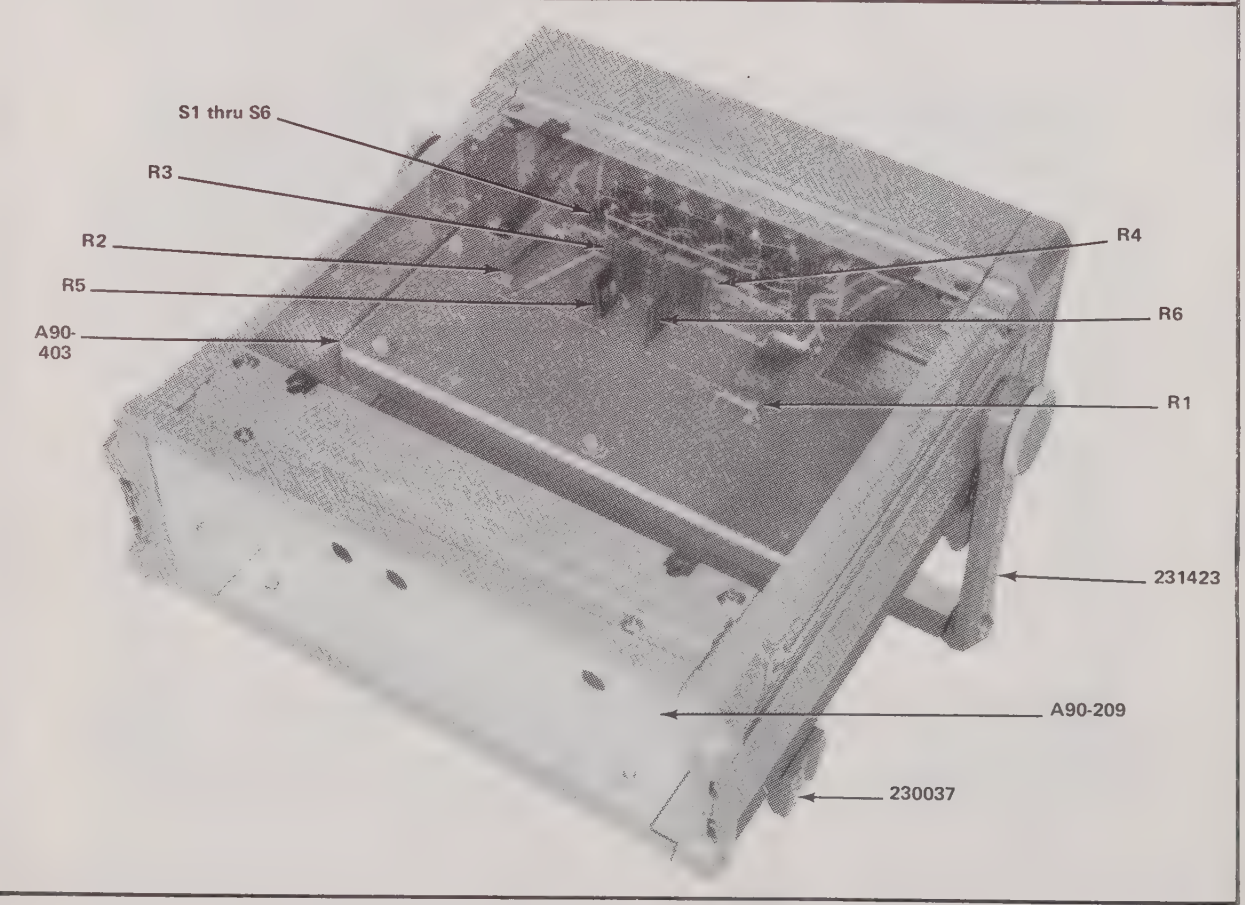
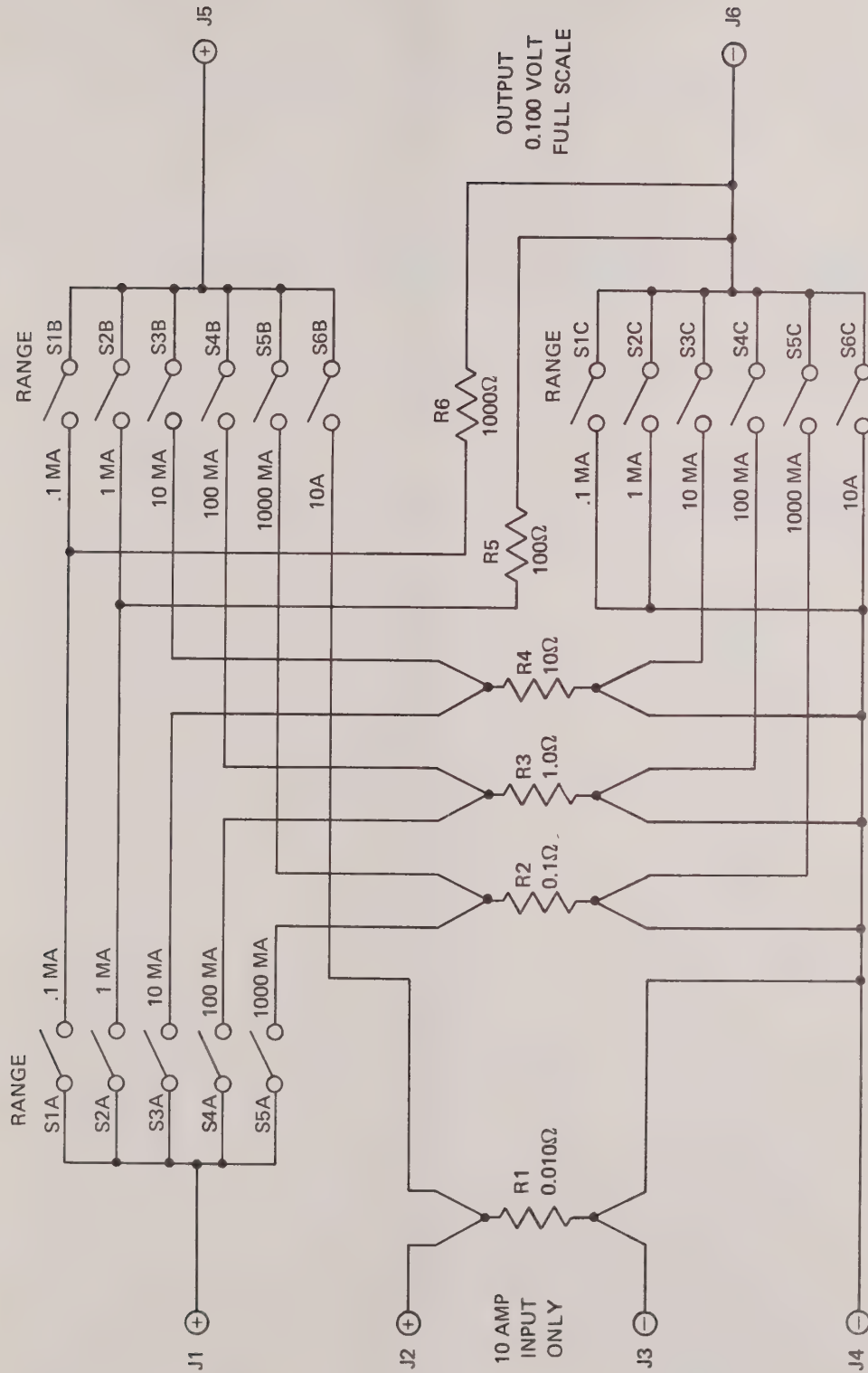


Figure 6-9. MODEL A90 CURRENT SHUNT (Sheet 2 of 2)



FUNCTIONAL SCHEMATIC DIAGRAM

MODEL A90

CURRENT SHUNT

SER. NO. 123 & ON

REV
3

FLUKE JOHN FLUKE MFG. CO., INC.
P.O. Box 7428 Seattle, Washington 98112

Federal Supply Code for Manufacturers

A-1. CODE TO NAME

A-2. The following five digit code numbers are listed in numerical sequence along with the manufacturer's

name and address to which the code has been assigned. The Federal Supply Code has been taken from Cataloging Handbook H 4-2, Code to Name.

00213	Sage Electronics Corp. Rochester, New York	03877	Transitron Electronic Corp. Wakefield, Massachusetts	05397	Union Carbide Corp. Electronics Div. New York, New York	07263	Fairchild Semiconductor Div. of Fairchild Camera & Instrument Corp. Mountain View, California
00327	Welwyn International, Inc. Westlake, Ohio	03888	Pyrofilm Resistor Co., Inc. Cedar Knolls, New Jersey	05571	Sprague Electric Co. Pacific Div. Los Angeles, California	07344	Bircher Co., Inc. Rochester, New York
00656	Aerovox Corp. New Bedford, Massachusetts	03911	Clairex Corp. New York, New York	05704	Alac, Inc. Glendale, California	07792	Lerma Engineering Corp. Northampton, Massachusetts
00686	Film Capacitors Passaic, New Jersey	03980	Muirhead Instruments, Inc. Mountainside, New Jersey	05820	Wakefield Engineering Ind. Wakefield, Massachusetts	07910	Teledyne Corp. (Continental Device) Hawthorne, California
00779	AMP Inc. Harrisburg, Pennsylvania	04009	Arrow Hart and Hegemen Electronic Company Hartford, Connecticut	06001	General Electric Company Capacitor Department Irmo, South Carolina	08225	Industro Transistor Corp. Long Island City, New York
01121	Allen-Bradley Co. Milwaukee, Wisconsin	04062	Replaced by 72136	06136	Replaced by 63743	08530	Reliance Mica Corp. Brooklyn, New York
01281	TRW Semiconductors Lawndale, California	04202	Replaced by 81312	06473	Amphenol Space & Missile Sys. Chatsworth, California	08792	Discontinued
01295	Texas Instruments, Inc. Semiconductor Components Div. Dallas, Texas	04217	Essex Wire Corp. Wire & Cable Div. Anaheim, California	06555	Beede Electrical Instrument Co. Penacook, New Hampshire	08806	General Electric Co. Miniature Lamp Dept. Cleveland, Ohio
01686	RCL Electronics Inc. Manchester, New Hampshire	04221	Aemco, Div. of Midtex Inc. Mankato, Minnesota	06739	Electron Corp. Littleton, Colorado	08863	Nylomatic Corp. Norrisville, Pennsylvania
01730	Deleted	04222	Aerovox Corp. (H-Q) Myrtle Beach, South Carolina	06743	Clevite Corp. Cleveland, Ohio	08988	Skottie Electronics Inc. Archbald, Pennsylvania
01884	Dearborn Electronics Inc. Orlando, Florida	04645	Replaced by 75376	06751	Semcor Div. Components Phoenix, Arizona	09353	C and K Components Watertown, Massachusetts
02114	Ferroxcube Corp Saugerties, New York	04713	Motorola Semiconductor Products Inc. Phoenix, Arizona	06860	Gould National Batteries Inc. City of Industry, California	09423	Scientific Components, Inc. Santa Barbara, California
02606	Replaced by 15801	05082	Replaced by 94154	06980	Varian	09922	Burndy Corp. Norwalk, Connecticut
02660	Amphenol-Borg Elect. Corp. Broadview, Illinois	05236	Jonathan Mfg. Co. Fullerton, California	06980	Varian-Eimac San Carlos, California	11236	CTS of Berne Berne, Indiana
02799	Arco Capacitors, Inc. Torrence, California	05277	Westinghouse Electric Corp. Semiconductor Dept. Youngwood, Pennsylvania	07115	Replaced by 14674	11237	Chicago Telephone of Calif., Inc. (CTC) Paso Robles, California
03508	General Electric Co. Semiconductor Products Syracuse, New York	05278	Replaced by 43543	07138	Westinghouse Electric Corp., Electronic Tube Division Elmura, New York	11358	Discontinued
03614	Replaced by 71400	05397	Union Carbide Corp. Electronics Div. Cleveland, Ohio	07256	Silicon Transistor Corp. Garden City, New York	11403	Best Products Co. Chicago, Illinois
03651	Replaced by 44655	05279	Southwest Machine & Plastic Co. Los Angeles, California				
03797	Ildema Corp. Compton, California						

11503	Keystone Mfg. Div. of Avis Industrial Corp. Warren, Michigan	15909	Replaced by 17870	28478	Deltrol Controls, Corp. Milwaukee, Wisconsin	66150	Winslow Tele-Tronics Inc. Asbury Park, New Jersey
11726	Qualidyne Corp. Santa Clara, California	16299	Corning Glass Raleigh, North Carolina	28480	Hewlett Packard Co. Palo Alto, California	70563	Amperite Company Union City, New Jersey
12014	Chicago Rivet & Machine Co. Bellwood, Illinois	16332	Replaced by 28478	28520	Heyman Mfg. Co. Kenilworth, New Jersey	70903	Belden Mfg. Co. Chicago, Illinois
12040	National Semiconductor Corp. Danbury, Connecticut	16473	Cambridge Scientific Ind. Inc. Cambridge, Maryland	29083	Monsanto, Co., Inc. Santa Clara, California	71002	Birnbach Radio Co., Inc. New York, New York
12060	Diodes, Inc. Chatsworth, California	16742	Paramount Plastics Downey, California	30323	Illinois Tool Works, Inc. Chicago, Illinois	71236	"ELMENCO" Willimantic, Connecticut
12136	Philadelphia Handle Co. Camden, New Jersey	16758	Delco Radio Div. of General Motors Kokomo, Indiana	32539	Mura Corp. Great Neck, New York	71400	Bussmann Mfg. Div. of McGraw - Edison Co. Saint Louis, Missouri
12323	Presin Co., Inc. Shelton, Connecticut	17069	Circuit Structures Lab. Upland, California	32767	Griffith Plastic Products Co. Burlingame, California	71450	CTS Corp. Elkhart, Indiana
12327	Freeway Washer & Stamping Co. Cleveland, Ohio	17856	Siliconix, Inc. Sunnyvale, California	32879	Advanced Mechanical Components Northridge, California	71468	ITT Cannon Electric Inc. Los Angeles, California
12400	Replaced by 75042	17870	Daven-Div of Thomas A. Edison Ind. - McGraw - Edison Co. Manchester, New Hampshire	32897	Erie Technological Products, Incorporated Frequency Control Div. Carlisle, Pennsylvania	71482	Clare, C. P. & Co. Chicago, Illinois
12617	Hamlin Inc. Lake Mills, Wisconsin	18083	Deleted	33173	General Electric Co., Tube Dept. Owensboro, Kentucky	71590	Centralab Div. of Globe Union Inc. Milwaukee, Wisconsin
12697	Clarostat Mfg. Co. Dover, New Hampshire	18178	Vactec Inc. Maryland Heights, Missouri	34333	Silcon General Westminster, California	71707	Coto Coil Co., Inc. Providence, Rhode Island
12749	James Electronics Chicago, Illinois	18612	Vishay Intertechnology Inc. Malvern, Pennsylvania	34335	Advanced Micro Devices. Sunnyvale, California	71744	Chicago Miniature Lamp Works Chicago, Illinois
12856	Micrometals Sierra Madre, California	18736	Voltronics Corp. Hanover, New Jersey	37942	Mallory, P. R. & Co., Inc. Indianapolis, Indiana	71785	Cinch Mfg. Co. & Howard B. Jones Div. Chicago, Illinois
12954	Dickson Electronics Corp. Scottsdale, Arizona	19429	Discontinued, use 89536	42498	National Company Melrose, Massachusetts	72005	Driver, Wilber B., Co. Newark, New Jersey
12969	Unitrode Corp. Watertown, Massachusetts	19451	Perine Machinery & Supply Co. Seattle, Washington	43543	Nytronics Inc. Transformer Co. Div. Alpha, New Jersey	72092	Replaced by 06980
13103	Thermalloy Co. Dallas, Texas	19701	Electra Mfg. Co. Independence, Kansas	44655	Ohmite Mfg. Co. Skokie, Illinois	72136	Electro Motive Mfg. Co. Willimantic, Connecticut
13511	Amphenol Corp. Los Gatos, California	20584	Enochs Mfg. Co. Indianapolis, Indiana	46671	Radio Corp. of America New York, New York	72259	Nytronics Inc. Berkeley Heights, New Jersey
13606	Sprague Electric Co. Transistor Div. Concord, New Hampshire	20891	Self-Organizing Systems, Inc. Dallas, Texas	49956	Raytheon Company Lexington, Maine	72354	Deleted
13839	Replaced by 23732	22767	ITT Semiconductors Div. of ITT Palo Alto, California	53021	Sanamo Electric Co. Springfield, Illinois	72619	Dialight Corp. Brooklyn, New York
14099	Semtech Corp. Newbury Park, California	23732	Tracor Rockville, Maryland	55026	Simpson Electric Company Chicago, Illinois	72653	G. C. Electronics Rockford, Illinois
14193	California Resistor Corp. Santa Monica, California	23880	Stanford Applied Engrng. Santa Clara, California	56289	Sprague Electric Co. North Adams, Massachusetts	72665	Replaced by 90303
14298	American Components, Inc. Conshohocken, Pennsylvania	24248	Southco Div. of South Chester Corp. Lester, Pennsylvania	58474	Superior Electric Co. Bristol, Connecticut	72794	Dzus Fastener Co., Inc. West Islip, New York
14655	Cornell-Dubilier Electronics Newark, New Jersey	24655	General Radio Co. West Concord, Massachusetts	60399	Torrington Mfg. Co. Torrington, Connecticut	72928	Gudeman Co. (Gulton Industries) Chicago, Illinois
14674	Discontinued, see 16299	24759	Lenox-Fugle Electronics Plainfield, New Jersey	62460	Deleted	72982	Erie Tech. Products Inc. Erie, Pennsylvania
14752	Electro Cube Inc. San Gabriel, California	25403	Amperex Electronic Corp. Semiconductor & Receiving Tube Division Slatersville, Rhode Island	63743	Ward Leonard Electric Co. Mount Vernon, New York	73138	Beckman Instruments Inc. Helipot Division Fullerton, California
14869	Replaced by 96853	27014	National Semiconductor Corp. Santa Clara, California	64834	West Mfg. Co. San Francisco, California	73293	Hughes Aircraft Co. Electron Dynamics Div. Torrence, California
15636	Elec-Trol Inc. Northridge, California	27264	Molex Products Downers Grove, Illinois	65092	Weston Instruments Inc. Newark, New Jersey	73445	Amperex Electronic Corp. Hicksville, New York
15801	Lenwal Electronics Inc. Framingham, Massachusetts	28425	Bohannon Industries Fort Worth, Texas			73559	Carling Electric Inc. Hartford, Connecticut
15818	Amelec Semiconductor Div. of Teledyne Inc. Mountain View, California					73586	Circle 1 Industries Trenton, New Jersey
15849	USI CO., Inc. Mt. Vernon, New York					73734	Federal Screw Products, Inc. Chicago, Illinois
15898	International Business Machines (IBM) Essex Junction, Vermont						

73743	Fischer Special Mfg. Co. Cincinnati, Ohio	80145	API Instruments Co. Chesterland, Ohio	86684	Radio Corp. of America Electronic Components & Devices Harrison, New Jersey	95263	Leecraft Mfg. Co. Long Island City, New York
73899	JFD Electronics Co. Brooklyn, New York	80183	Sprague Products North Adams, Massachusetts	86689	Deleted	95264	Replaced by 98278
73949	Guardian Electric Mfg. Co Chicago, Illinois	80294	Bourns Inc. Riverside, California	87034	Marco-Oak Inc. Anaheim, California	95275	Vitramon Inc. Bridgeport, Connecticut
74199	Quam Nichols Co. Chicago, Illinois	80583	Hammarlund Co., Inc. Mars Hill, North Carolina	88245	Litton Products Inc. Van Nuys, California	95303	Radio Corp. of America Solid State & Receiving Tube Div. Cincinnati, Ohio
74217	Radio Switch Corp. Marlboro, New Jersey	80640	Stevens, Arnold Inc. Boston, Massachusetts	88419	Use 14655	95354	Methode Mfg. Corp. Rolling Meadows, Illinois
74276	Signalite Inc. Neptune, New Jersey	81073	Grayhill Inc. La Grange, Illinois	88690	Replaced by 04217	95712	Dage Electric Co., Inc. Franklin, Indiana
74306	Piezo Crystal Co. Carlisle, Pennsylvania	81590	Korby Mfg. Co. Seattle, Washington	89536	Fluke, John Mfg. Co., Inc. Seattle, Washington	95987	Weckesser Co., Inc. Chicago, Illinois
74542	Hoyt Elect. Instr. Works Penacook, New Hampshire	81312	Winchester Electronics Div. of Litton Industries Oakville, Connecticut	89730	Replaced by 08806	96733	San Fernando Electric Mfg. Co. San Fernando, California
74970	Johnson, E. F., Co. Waseca, Minnesota	81439	Therm-O-Disc Inc. Mansfield, Ohio	90201	Mallory Capacitor Co. Indianapolis, Indiana	96853	Rustrak Instrument Co. Manchester, New Hampshire
75042	IRC Inc. (Div. of TRW) Philadelphia, Pennsylvania	81483	International Rectifier Corp. Los Angeles, California	90215	Best Stamp & Mfg. Co Kansas City, Missouri	96881	Thomson Industries, Inc. Manhasset, New York
75376	Kurz-Kasch, Inc. Dayton, Ohio	82376	Deleted	90211	Square D Co. Chicago, Illinois	96881	Thomson Industries, Inc. Manhasset, New York
75382	Kulka Electric Corp. Mount Vernon, New York	82389	Switchcraft Inc. Chicago, Illinois	90303	Mallory Battery Co. Tarrytown, New York	97540	Master Mobile Mounts Div. of Whitehall Electronics Corp. Los Angeles, California
75915	Littlefuse Inc. Des Plaines, Illinois	82415	Price Electric Corp. Frederick, Maryland	91293	Johanson Mfg. Co. Boonton, New Jersey	97913	Industrial Electronic Hdware Corp. New York, New York
76854	Oak Mfg. Co. Crystal Lake, Illinois	82872	Roanwell Corp. New York, New York	91407	Replaced by 58474	97945	White, S. S. Co. Plastics Div. New York, New York
77342	Potter & Brumfield Div. of Amer. Machine & Foundry Princeton, Indiana	82877	Rotron Mfg. Co., Inc. Woodstock, New York	91502	Associated Machine Santa Clara, California	97966	Replaced by 11358
77969	Rubbercraft Corp. of Calif. LTD. Torrance, California	82879	ITT Wire & Cable Div. Pawtucket, Rhode Island	91637	Dale Electronics Inc. Columbus, Nebraska	98094	Replaced by 49956
78189	Shakeproof Div. of Illinois Tool Works Elgin, Illinois	83003	Varo Inc. Garland, Texas	91662	Elco Corp. Willow Grove, Pennsylvania	98159	Rubber-Teck, Inc. Gardena, California
78277	Sigma Instruments, Inc. South Braintree, Massachusetts	83298	Bendix Corp. Electric Power Division Eatontown, New Jersey	91737	Gremar Mfg Co., Inc. (ITT) Woburn, Massachusetts	98278	Microdot Inc. Pasadena, California
78488	Stackpole Carbon Co. Saint Marys, Pennsylvania	83330	Smith, Herman H., Inc. Brooklyn, New York	91802	Industrial Devices, Inc. Edgewater, New Jersey	98291	Sealectro Corp. Conhex Div. Mamaroneck, New York
78553	Tinnerman Products Cleveland, Ohio	83478	Rubbercraft Corp. of America New Haven, Connecticut	91836	King's Electronics Tuckahoe, New York	98388	Accurate Rubber & Plastics Culver City, California
79136	Waldes Kohinoor Inc. Long Island City, New York	83594	Burroughs Corp. Electronic Components Div. Plainfield, New Jersey	91929	Honeywell Inc. Micro Switch Div. Freeport, Illinois	98743	Replaced by 12749
79497	Western Rubber Company Goshen, Indiana	83740	Union Carbide Corp. Consumer Products Div. New York, New York	91934	Muller Electric Co., Inc. Pawtucket, Rhode Island	98925	Deleted
79963	Zierick Mfg. Corp. New Rochelle, New York	84171	Arco Electronics, Inc. Great Neck, New York	93332	Sylvania Electric Products Semiconductor Products Div Woburn, Massachusetts	99120	Plastic Capacitors, Inc. Chicago, Illinois
80031	Mecpo Div. of Sessions Clock Co. Morristown, New Jersey	84411	TRW Ogallala, Nebraska	94145	Replaced by 49956	99217	Southern Electronics Corp. Burbank, California
		86577	Precision Metal Products Stoneham, Massachusetts	94154	Tung-Sol Div. of Wagner Electric Corp. Newark, New Jersey	99515	Marshall Industries Capacitor Div. Monrovia, California
				95146	Alco Electronics Products Inc. Lawrence, Massachusetts	99779	Barnes Corp. Lansdowne, Pennsylvania

List of Abbreviations

A , amp	ampere(s) (2.1A, 2.1 amp)	met flm	metal film
ampl	amplifier	MOS	metal oxide silicon
ac	alternating current	μ	micro or 10^{-6} (60 μ V)
assy	assembly	m	milli or 10^{-3}
@	at	mA	milliampere(s)
BCD	binary coded decimal	mm	millimeter
cap	capacitor	n	nano or 10^{-9}
cm	centimeter	neg	negative
C	clear; reset	Ω	ohm
$^{\circ}$ C	celsius or centigrade (0° C)	scope	oscilloscope
cer	ceramic	ppm	parts per million
clk	clock	prv	peak inverse voltage
cw	clockwise	p-p	peak to peak
CMRR	common mode rejection ratio	p	pico or 10^{-12} (300pF)
cbn cmpsn	carbon composition	plstc	plastic
ccw	counterclockwise	$\pm$	plus or minus
conn	connector	pos	positive
cbn flm	carbon film	pps	pulses per second
CRT	cathode ray tube	PCB	printed circuit board
cps	cycles per second (Hz preferred)	QTY	quantity
dB	decibel	rf	radio frequency
dep cbn	deposited carbon	rfi	radio frequency interference
dvm	digital voltmeter	RECM	recommended
dio	diode	REF	reference
dc	direct current	RH	relative humidity
dpdt	double-pole, double-throw	res	resistor
dpst	double-pole, single-throw	rms	root mean square
elctlt	electrolytic	rtry	rotary
elek	electronic (equip.)	s	second
elcx	electronics (science)	sect	section
ext	external	SERNO	serial number
$^{\circ}$ F	fahrenheit (32° F)	Si	silicon
F	farad	scr	semiconductor controlled rectifier
FET	field effect transistor	spdt	single-pole, double-throw
Ge	germanium	spst	single-pole, single-throw
g	giga or 10^9	sw	switch
G	gravity	Ta	tantalum
gnd	ground	TC	temperature coefficient
gmV	guaranteed minimum value	t	tera or 10^{12}
gd	guard	xfmr	transformer
h	henry	xstr	transistor
Hz	Hertz (60Hz, 60GHz, 60 gigahertz)	tvm	transistor voltmeter
hf	high frequency	uhf	ultra high frequency
"	inch(es) (6 3/4" or 0.575 feet)	vtvm	vacuum tube voltmeter
IC	integrated circuit	var	variable
if	intermediate frequency	vs	versus
intl	internal	vhf	very high frequency
kc	kilocycle (kilohertz preferred)	vlf	very low frequency
k	kilo or 10^3	V	volt (115Vac)
lf	low frequency	VCO	voltage controlled oscillator
mc	megacycle (megahertz preferred)	w	watt
M	meg or mega or 10^6	ww	wire wound
met	metal		

Appendix C

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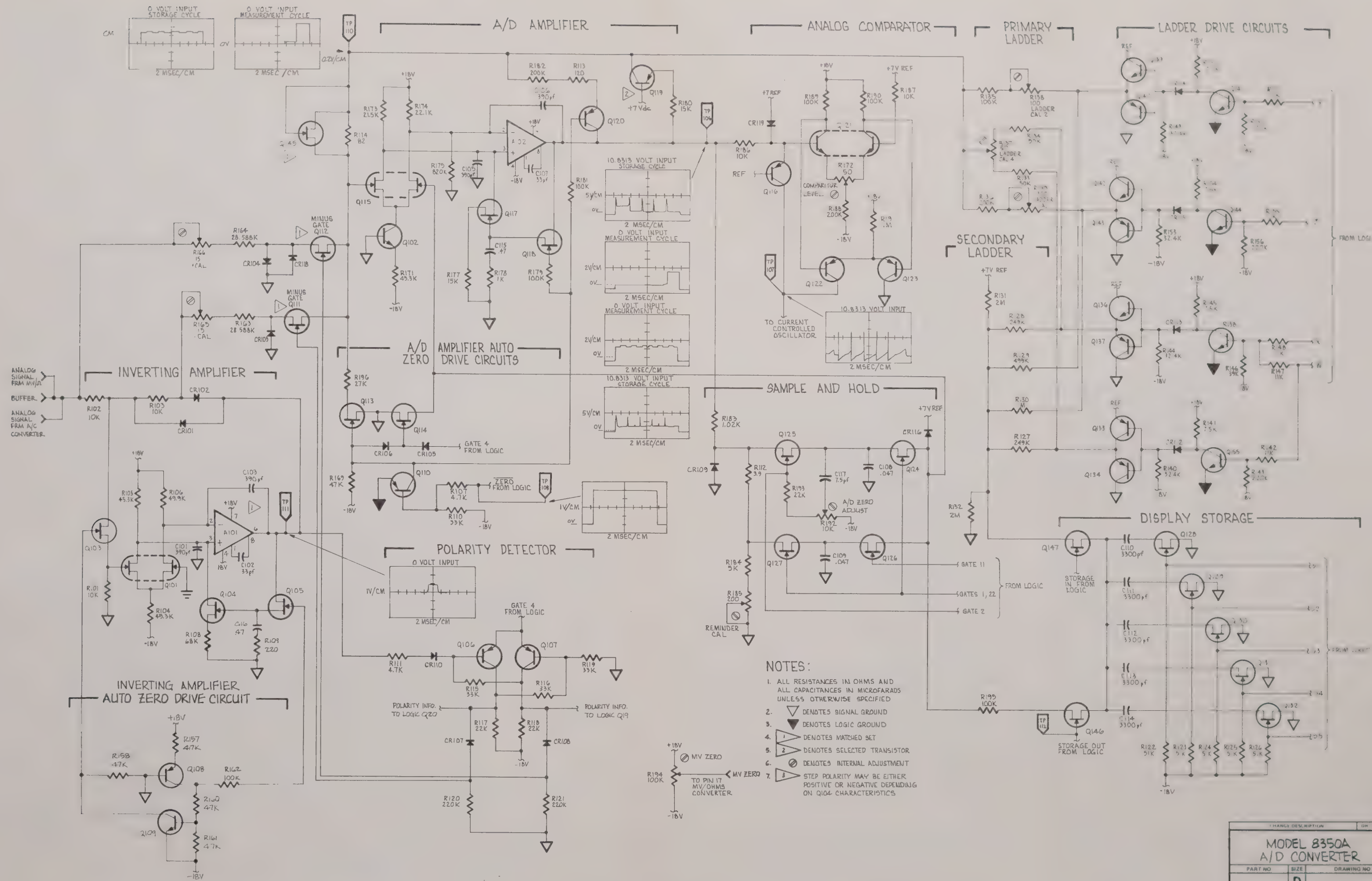
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TILBURG, THE NETHERLANDS

FLUKE REGIONAL SERVICE CENTER, UNITED KINGDOM

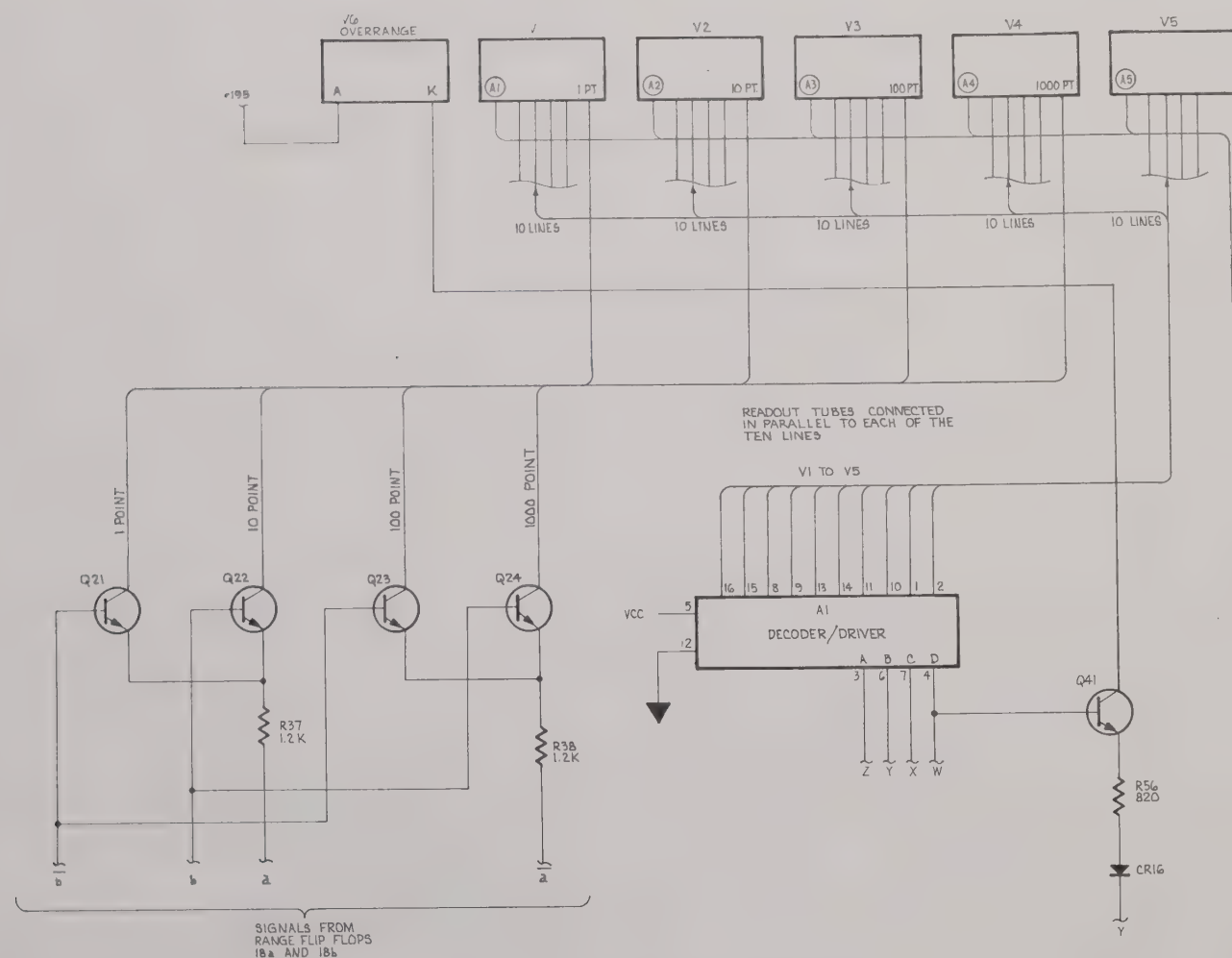
FLUKE INTERNATIONAL CORP.
GARNETT CLOSE
WATFORD, WD2 4TT
ENGLAND

AUTHORIZED SERVICE LABORATORIES INTERNATIONAL

EACH INTERNATIONAL REPRESENTATIVE IS EQUIPPED WITH AN
AUTHORIZED SERVICE LABORATORY. PLEASE REFER TO THE
INTERNATIONAL REPRESENTATIVE LISTING FOR YOUR SERVICE NEEDS.



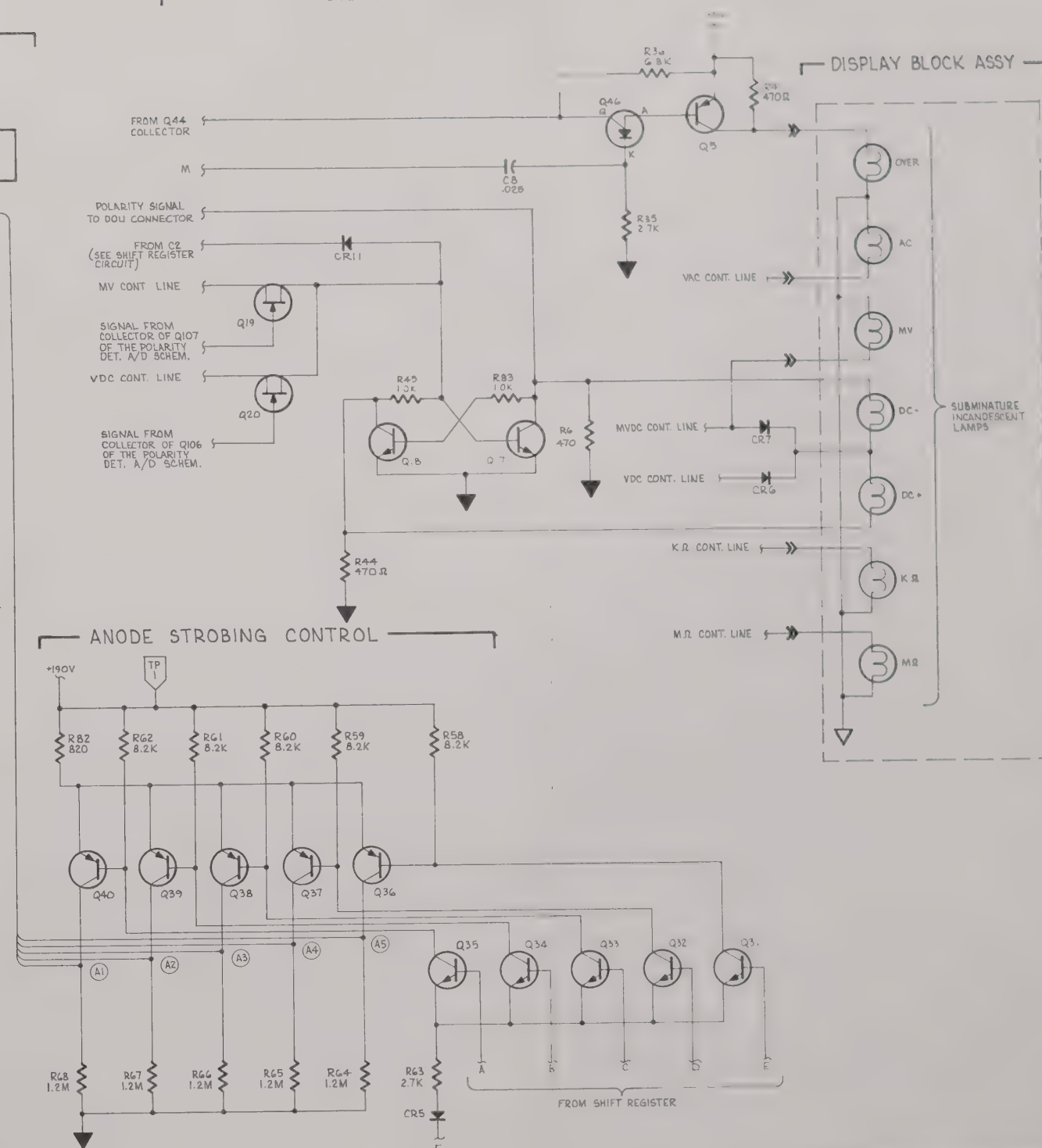
READOUT TUBES FRONT PANEL



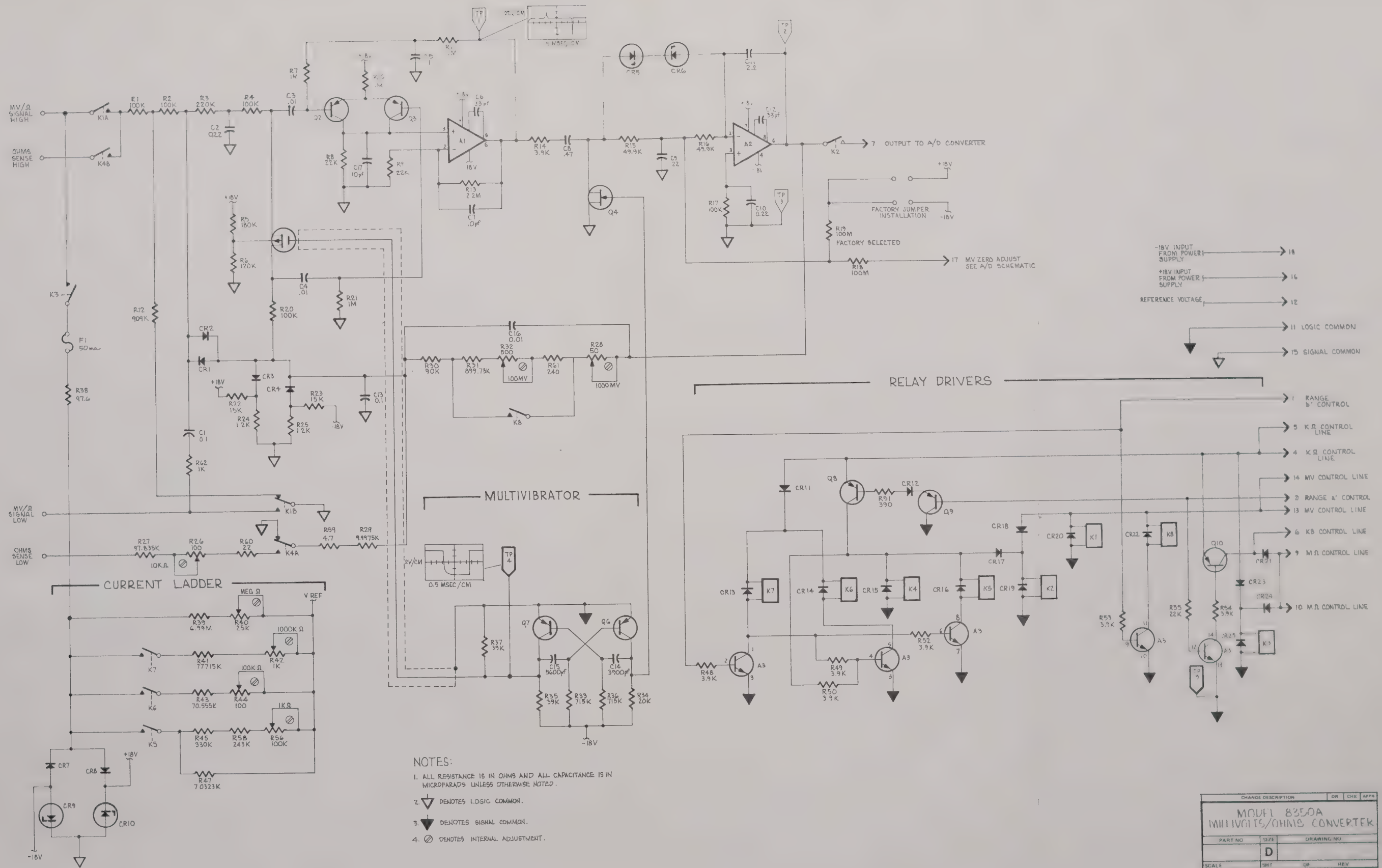
NOTES:

1. ALL RESISTANCES IN OHMS AND ALL CAPACITANCES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

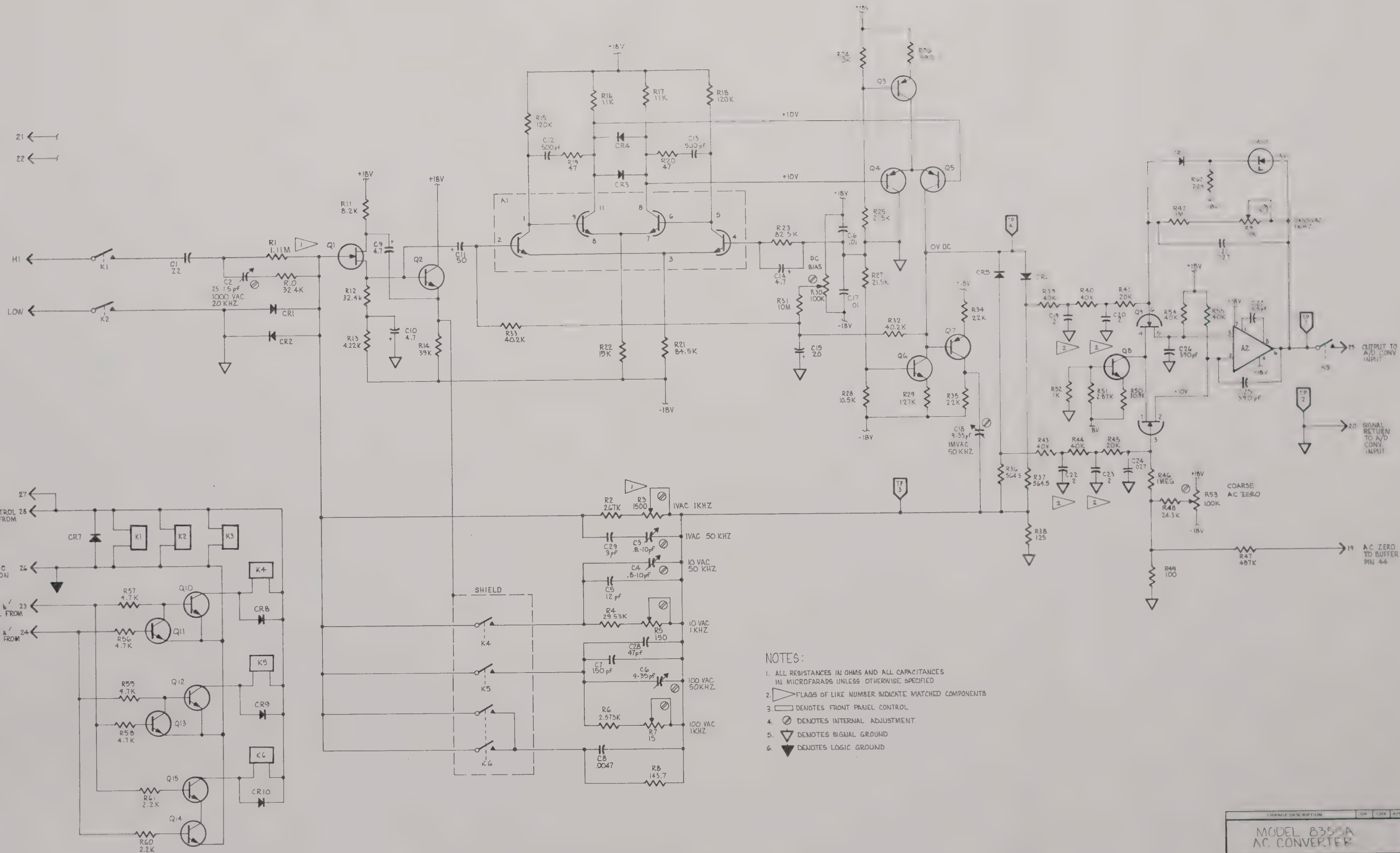
DISPLAY CIRCUITRY



CHANGE DESCRIPTION		DATE	BY	APP'D
MODEL 8350A DISPLAY				
PART NO.	8378	DRAWING NO.		
	D			
SCALE	SHR	OF	REV.	



+18V 21 ←
-18V 22 ←



NOTES:

1. ALL RESISTANCES IN OHMS AND ALL CAPACITANCES IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. FLAGS OF LIKE NUMBER INDICATE MATCHED COMPONENTS
3. DENOTES FRONT PANEL CONTROL
4. DENOTES INTERNAL ADJUSTMENT
5. DENOTES SIGNAL GROUND
6. DENOTES LOGIC GROUND

CHANGE DESCRIPTION		OR	REV	APPV
MODEL 8350A AC CONVERTER				
PART NO.	SIZE	DRAWING NO.		
	D			
SCALE	SMT	OF	REV	



87265